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Case Study in San Francisco

Metcalf and Eddy, Inc.
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URBAN STORMWATER MANAGEMENT AND TECHNOLOGY: CASE STUDY SAN FRANCISCO

by

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16. ABSTRACT

This report is the fourth in a series on urban stormwater and combined sewer overflow (CSO) management. It presents San Francisco's experience with the planning and design of CSO control and treatment facilities. The development of the San Francisco combined sewer overflow control master plan has been a continuing process for over 10 years. The case history presents the approach used to balance the combined wastewater overflow treatment needs with the costs and environmental/social impacts in a large urban area.

The overall control system is a combination of storage, transport, and treatment facilities. The array of system alternatives available to meet receiving water quality needs were evaluated on the basis of engineering, cost, environmental, and social benefits. Marginal cost-benefit analyses were used to establish the annual frequency of combined sewage overflow occurrences.

The methodology used to narrow down the available system configuration alternatives from 38 to 5 and then to 1 is described. The selected CSO control master plan is presented including expected performance, costs, and water quality impacts.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

As the nation moves closer to its goals of clean water by implementing programs that control urban stormwater runoff and combined sewer overflows, the experience gained from operating full-scale control facilities becomes invaluable. Using this experience in future planning and design is an essential step in implementing cost-effective systems for urban stormwater pollution control.

Francis T. Mayo
Director
Municipal Environmental Research Laboratory

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The report is submitted in partial fulfillment of Contract No. 68-03-2877 by Metcalf & Eddy, Inc., Western Regional Office, under the sponsorship of the U.S. Environmental Protection Agency.

CONTENTS

Foreword iii
Abstract iv
Figures vi
Tables vii

Section		Page
1	INTRODUCTION	1
2	STUDY AREA CHARACTERISTICS	2
3	PROBLEM ASSESSMENT	7
	Wet-Weather Flow and Load	8
	Discharge Regulations	9
	Basin Plan and Ocean Plan	10
	NPDES Permits	14
4	MASTER PLAN DEVELOPMENT AND SELECTION	16
	Current Wastewater Management Projects	16
	System Configuration Development and Selection	24
	Reduction from Five Alternatives to One Alternative	27
	Cost Ranking	28
	Engineering Ranking	30
	Selection of Wastewater Management Plan	31
	Marginal Cost/Benefit Analysis	32
	Risk Assessment	33
	Conclusion	36
5	SELECTED COMBINED SEWER OVERFLOW CONTROL MASTER PLAN	37
	Flow Routing	37
	Level of Treatment	39
	Performance	40
	Operation and Maintenance	43
	Costs	44
	Environmental/Socioeconomic Benefits	46
6	CONTINUING ANALYSIS	47
	REFERENCES	49
	TECHNICAL REPORT DATA SHEET	50

FIGURES

Number		Page
1	Site location	2
2	Storm magnitude versus frequency	4
3	Storm intensity versus frequency	4
4	Storm duration versus frequency	5
5	Existing water pollution control plant and combined sewer overflow locations	6
6	Beach closing, a common "winter" occurrence under existing conditions	7
7	Potential bay beneficial use water quality summary	11
8	Potential ocean beneficial use water quality summary	12
9	1971 Master plan for wet-weather wastewater flow management	20
10	Wastewater flow management facilities currently under construction	22
11	Construction photographs, San Francisco Clean Water Program	23
12	Master Alternative 1 with variations, ocean discharge	25
13	Master Alternatives 2, 3, and 4 with variations	26
14	Overflow total suspended solids emissions versus wet-weather capital costs - Master Plan 1B	34
15	Average annual coliform violation days versus wet-weather capital costs - Master Plan 1B	35
16	Schematic of apparent best alternative wet-weather system	38
17	Generalized cost allocations	45
18	Program for Staged Construction	48

TABLES

Number		Page
1	Annual and Monthly Rainfall	1
2	Treatment Plants in San Francisco	5
3	Projected Stormwater Flow and Pollutant Loads	8
4	Projected Stormwater Characteristics after Storage and Treatment by Existing Facilities	9
5	Beneficial Uses of Surface Waters, Basin and Ocean Plans	10
6	Summary of Coliform Standards	13
7	Summary of Wet-Weather NPDES Permits	14
8	Chronology of Master Plan Development	17
9	Cost Estimates of Five Alternatives	28
10	Weighting of Evaluation Factors	29
11	Ranking of Alternatives - Cost Factors	29
12	Ranking of Alternatives - Environmental/Social Factors	30
13	Ranking of Alternatives - Engineering Factors	31
14	Summary of Evaluation Factor Group Rankings	31
15	Comparison of Several Parameters for Various Overflow Frequencies	32
16	Comparison of Reduction Percentages for Several Parameters for Various Overflow Frequencies	32
17	Comparison of Incremental Capital Costs for Several Parameters for Various Overflow Frequencies	33
18	Expected Effluent Quality from Southwest WPCP	40
19	System Effectiveness Comparison of Overflow Reductions	41
20	Monthly Distribution of Average/Expected Maximum Overflow Occurrences under the Apparent Best Alternative	42
21	Monthly Distribution of Violation Days Under Apparent Best Alternative	42
22	Selected Computed Influent Loadings to Southwest WPCP Wet-Weather Plant	44
23	Systemwide Costs of the Selected Master Plan	45

SECTION 1

INTRODUCTION

The development of the San Francisco Master Plan to control combined sewer overflows exemplifies the problems and constraints faced by many large, fully developed urban areas. For over a decade, improving technology, public interest groups, and political factions have played an important role in shaping the master plan. The individual elements of the master plan were and continue to be developed under changing water quality regulations and effluent discharge limits, as well as shifting national and local fiscal priorities. The resulting master plan represents a cost-effective, yet flexible, solution developed under real-life constraints.

This case history focuses on the methodology of the present and continuing development of the San Francisco Master Plan. The methodology uses receiving water quality criteria and cost-benefit analyses to establish allowable systemwide overflows that set treatment plant design flows. The basic system configuration and the integration of storage, transport, and treatment facilities of the proposed citywide control facilities are also described. Finally, the expected performance of the system and proposed treatment plant, capital and operation and maintenance costs, and related water quality and socioeconomic impacts are presented.

The use of a computer model permitted the quantitative determination of combined wastewater flow and quality. The computer model, SFMAC, was developed for this project [1]. The model computes systemwide combined wastewater flow volumes based on system flow records, rainfall records, and assumed runoff coefficients, as well as projected raw wastewater quality based on representative quality measurements. This model also estimates the change in wastewater quality after passage through existing and proposed storage, conveyance, and treatment facilities. SFMAC was an indispensable tool in the assessment of the combined sewer overflow problem and in the development of the master plan.

This case history reflects the program status as of January 1981. As noted in Section 6, a staged program for construction has been adopted with each element subject to continuing analysis as changing goals, priorities, and constraints are encountered and addressed.

SECTION 2

STUDY AREA CHARACTERISTICS

San Francisco is located at the northern end of a peninsula consisting of a cluster of hills that forms part of the coastal mountain range in northern California. The topography of the city is characterized by dozens of peaks located throughout the city, steep headlands on its northwestern shoreline, and a flat eastern coastal strip. Large areas of the northeastern shoreline have been reclaimed from San Francisco Bay.

San Francisco has approximately 39 km (24 miles) of shoreline. One-third of the shoreline is bounded by the Pacific Ocean on the west. San Francisco Bay borders the northern and eastern shores of the city. A location map is shown in Figure 1.

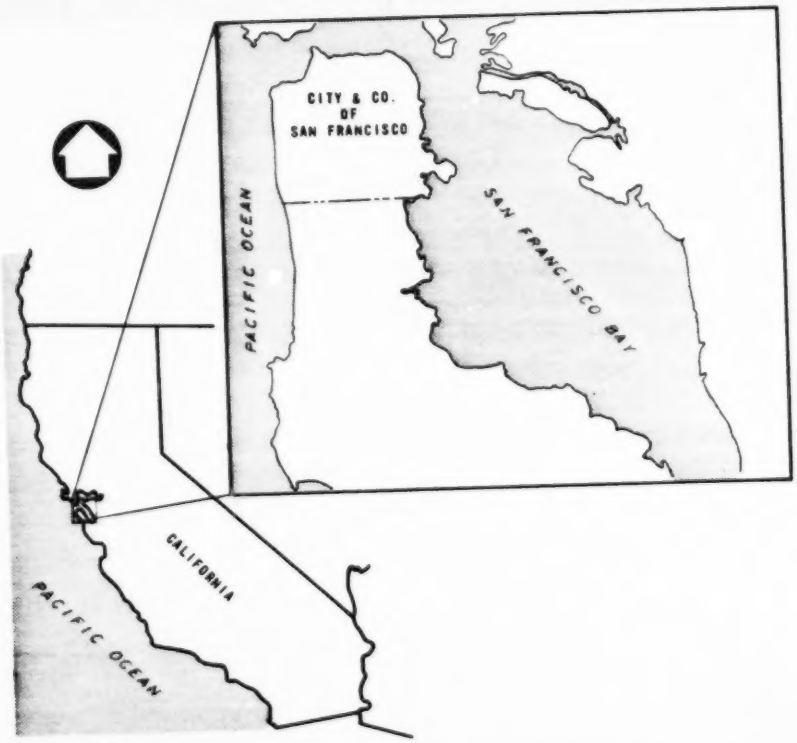


Figure 1. Site location.

Due to its marine environment, San Francisco has a mild climate. Average temperatures range from 7 °C (45 °F) in January to 21 °C (69 °F) in September with few days of extreme temperatures.

Average annual rainfall is approximately 50.8 cm (20 in.) with 84% of the rainfall occurring from November to March. Average monthly rainfall is shown in Table 1. This rainfall pattern produces high overflow volumes and increased pollutant discharges to the bay and ocean during the winter months.

Table 1. ANNUAL AND MONTHLY RAINFALL

	Average rainfall, in.	% of annual
January	4.57	22.5
February	3.36	16.5
March	2.80	13.8
April	1.43	7.0
May	0.59	2.9
June	0.14	0.7
July	0.02	0.1
August	0.02	0.1
September	0.24	1.2
October	0.89	4.4
November	2.24	11.0
December	4.03	19.8
Total	20.33	100.0

in. x 2.54 = cm

Storms over the city tend to have moderate to long durations. Of the 55 storms occurring in the average year, half are 6 hours or longer. Rainfall characteristics, based on the National Weather Service's 70 year rainfall record, are shown in Figures 2, 3, and 4.

San Francisco has 1,400 km (870 miles) of combined sewer pipelines serving 11,550 ha (28,550 acres). This system has 39 overflow structures that discharge combined sewage into the bay and ocean when the collection system or treatment plants' capacities are exceeded, primarily during the rainy winter months. Currently, there are 22 pump stations in the city.

Three primary wastewater treatment plants serve each of the three main watersheds. The Richmond-Sunset Water Pollution Control Plant (WPCP) treats combined wastewater from the 4,210 ha (10,403 acre) Westside District watershed with residential and public land uses. This plant discharges to the Pacific Ocean. The North Point WPCP treats combined wastewater from 3,520 ha (8,687 acres) of the primarily commercial North Point District watershed. The Southeast WPCP serves 3,830 ha (9,460 acres) of residential and industrial land in the Southeast District watershed. The latter two plants discharge into San Francisco Bay. The locations of the treatment plants and combined sewer overflow structures are shown in Figure 5.

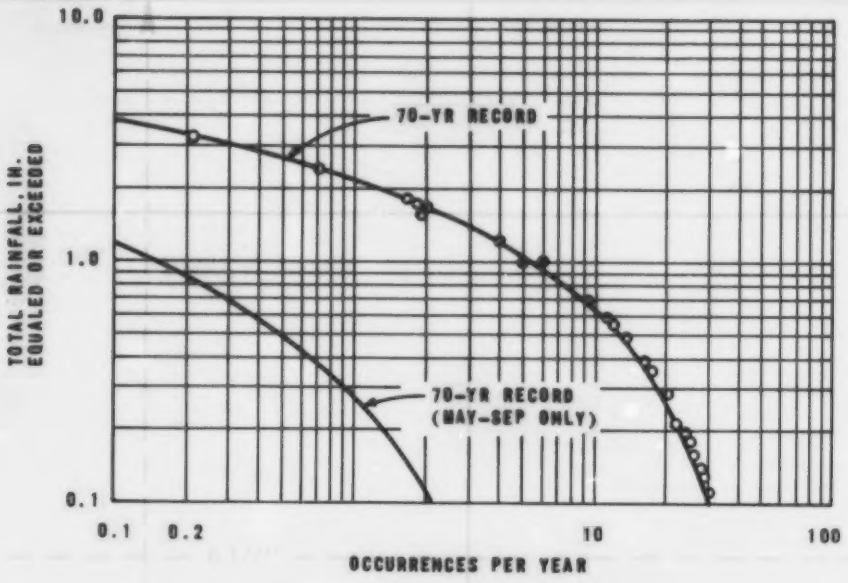


Figure 2. Storm magnitude versus frequency.

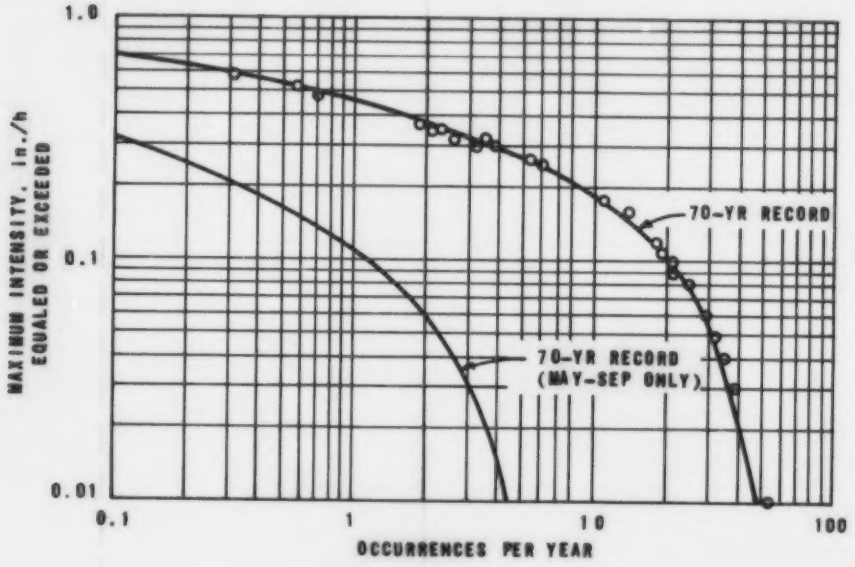


Figure 3. Storm intensity versus frequency.

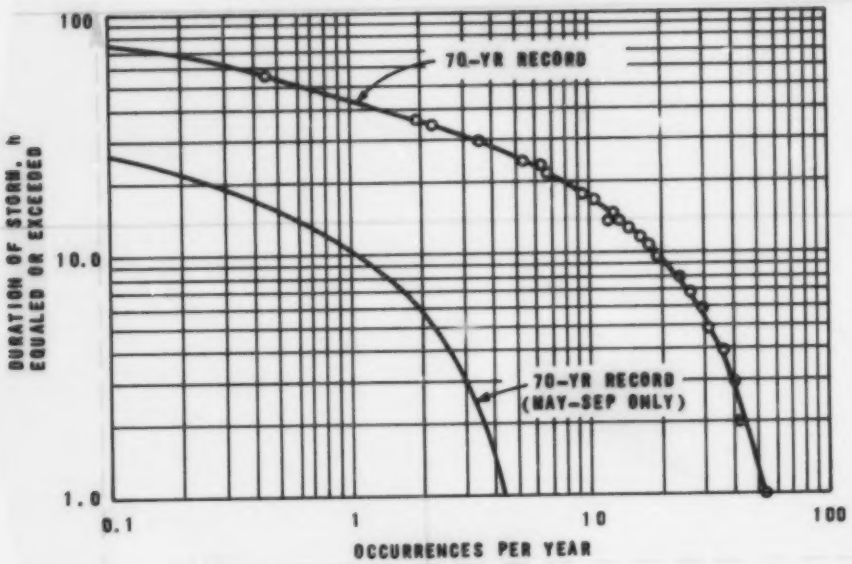


Figure 4. Storm duration versus frequency.

The Southeast WPCP is currently being expanded and upgraded to a secondary treatment facility. This plant will treat all dry-weather flows from the bayside (North Point and Southeast districts). The North Point District is composed of two major subareas, North Shore and Channel. When the expanded Southeast WPCP goes on line, the Channel subarea will become part of the Southeast District. In the remainder of this report, references to the Southeast District include the Channel subarea. Pertinent data on the existing and expanded treatment plants are presented in Table 2.

Table 2. TREATMENT PLANTS IN SAN FRANCISCO

Name	Design capacity, Mgal/d	Function	Level of treatment	Initial year of operation	Peak hydraulic capacity, Mgal/d
Richmond-Sunset	23	Dry-weather treatment	Primary	1939	70
North Point	65	Dry-weather treatment	Chemically assisted primary[a]	1951	150
Southeast	30	Dry-weather treatment	Chemically assisted primary[a]	1951	70
Southeast expansion[b]	85.4	Dry-weather treatment	High purity oxygen activated sludge	--	142

a. Primary treatment without chemical addition prior to 1972.

b. Will replace and integrate existing North Point and Southeast plants, respectively.

Mgal/d x 0.0438 = m^3/s

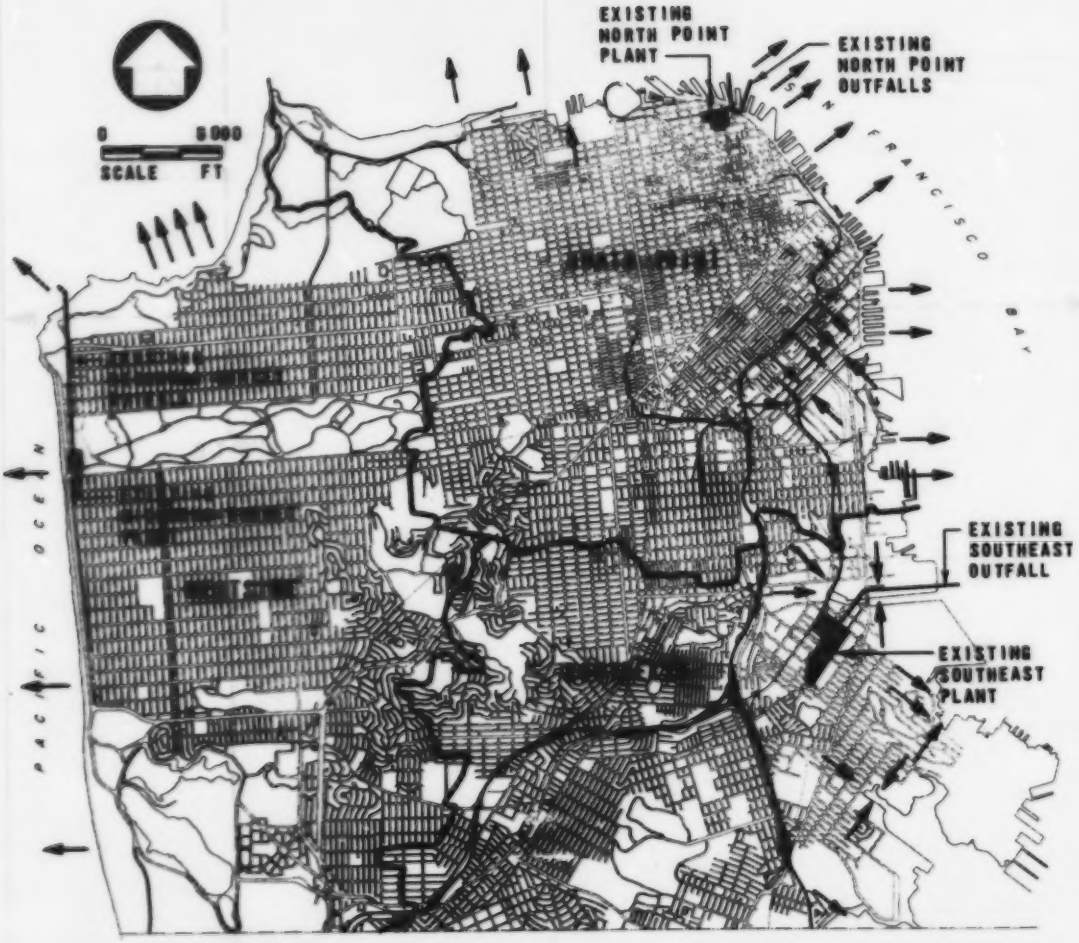


Figure 5. Existing water pollution control plant and combined sewer overflow locations.

SECTION 3

PROBLEM ASSESSMENT

San Francisco's combined sewer system carries both municipal wastewater and intercepted surface runoff. Stormwater runoff from intense rainfall in San Francisco can exceed municipal wastewater volume by 50 to 100 times. Depending on the topography, level of development, and prestorm conditions, an average of 50 to 75% of the city's rainfall becomes runoff that enters the sewer system, mixes with municipal wastewater, and if not treated, overflows to the ocean and bay. The present collection and treatment systems are able to accommodate only small amounts of stormwater runoff, approximately 0.05 cm (0.02 in.) of rain per hour, before overflowing to the ocean and bay. Beach postings (closings), as shown in Figure 6, are common through the wet-weather season spanning several months each year.

Ocean Beach, a part of the Golden Gate National Recreation Area (GGNRA), is estimated by the National Park Service to attract over a million visitors per year. Monitored by the Department of Public Health and posted after every storm, technical bacterial violation days are expected to be reduced from 170 to less than 30 days per year through implementation of the Clean Water Program Master Plan.

Figure 6. Beach closing, a common "winter" occurrence under existing conditions.

WET-WEATHER FLOW AND LOAD

Projected wet-weather flow and pollutant loads developed from computer simulation are shown in Table 3. These loads, based on historical rainfall, represent raw stormwater characteristics before the stormwater is combined with municipal wastewater, stored, or treated.

Table 3. PROJECTED STORMWATER FLOW AND POLLUTANT LOADS

	Drainage area	
	Westside	Bayside (North Shore and Southeast)
Flow		
Avg annual volume, Mgal	2,896	5,174
Maximum monthly volume, Mgal	651	1,163
Peak hourly rate, Mgal/d		
3 month storm	998	2,114
6 month storm	1,273	2,698
1 year storm	1,548	3,281
5 year storm	2,167	4,593
Biochemical oxygen demand		
Avg annual load, 1,000 lb	1,352	2,416
Maximum monthly load, 1,000 lb	304	543
Peak hourly load, 1,000 lb		
3 month storm	23.6	50.0
6 month storm	30.1	63.8
1 year storm	36.6	77.6
5 year storm	51.3	108.6
Suspended solids		
Avg annual load, 1,000 lb	4,034	7,200
Maximum monthly load, 1,000 lb	907	1,618
Peak hourly load, 1,000 lb		
3 month storm	62.1	131.6
6 month storm	79.2	167.9
1 year storm	96.4	204.3
5 year storm	134.9	286.0

Note: 3 month storm - storm which occurs an average of 4 times per year

6 month storm - storm which occurs an average of 2 times per year

1 year storm - storm which occurs an average of 1 time per year

5 year storm - storm which occurs an average of once every 5 years.

Mgal x 0.0438 = m^3
lb x 0.4536 = kg

The characteristics of the stormwater, after it is routed through the city's existing storage and treatment system (including those facilities under construction), are presented in Table 4. The 39 overflow structures discharge combined wastewater an average of 68 times a year, dumping 3,790,000 kg (8,357,000 lb) of TSS and 1,570,000 kg (3,465,000 lb) of BOD into the bay and ocean.

Table 4. PROJECTED STORMWATER CHARACTERISTICS AFTER STORAGE AND TREATMENT BY EXISTING FACILITIES[a]

	Drainage area			
	Westside	North Shore	Southeast	Citywide
Weighted avg annual overflow				
Hours	300	136	360	319
Events	71	18	74	68
Avg annual load in overflows, 1,000 lb				
BOD	1,040	248	2,177	3,465[b]
TSS	2,763	592	5,002	8,357[b]
Avg annual violation days	188	128	276	197

a. Includes benefits of components committed to construction through 1979.

b. Citywide total

lb x 0.4536 = kg

Average annual violation days number 197. Violation days are the number of days receiving water coliform levels exceed regulatory agency standards. Violation days exceed the number of overflow events and days with rainfall due to the long die-off period of coliform bacteria in the receiving water. There are three body contact recreation and two shellfish standards. The number of violations shown in Table 4 were computed using the most stringent body contact recreation standards for the Westside and North Shore drainage areas and the most stringent shellfish standards for Southeast area. This violation day analysis indicates that bay and ocean waters do not meet these criteria on more than half the days in an average year.

DISCHARGE REGULATIONS

The current wastewater collection and treatment system performance, as presented previously, does not meet state and federal regulations. State and regional agencies have established treatment and discharge requirements in compliance with the 1972 Federal Water Pollution Control Act (PL 92-500). The three major sets of documents containing these requirements are the Basin Plan, Ocean Plan, and National Pollution Discharge Elimination System (NPDES)

permits. These three documents provided the guidelines for developing the master plan for the City and County of San Francisco.

Basin Plan and Ocean Plan

In April 1975, the Regional Water Quality Control Board (RWQCB) and State Water Resources Control Board (SWRCB) adopted the Water Quality Control Plan, San Francisco Bay Basin (Basin Plan), which contains water quality objectives for both San Francisco Bay and the Pacific Ocean. This comprehensive water quality control plan provides the basis for developing facilities plans that meet requirements for state and federal construction grant funds.

In June 1978, the SWRCB adopted Amendments to the Water Quality Plan for the Ocean Waters of California (Ocean Plan). This document contains water quality objectives for the Pacific Ocean and serves as a guide in establishing effluent limitations.

Together, these documents define beneficial uses of receiving water, water contact recreation and shellfish coliform standards, and discharge conditions. The coliform standards and discharge conditions are directed toward maintaining the existing beneficial uses and improving receiving water quality for potential beneficial uses.

The beneficial uses of the waters surrounding San Francisco, as defined by the Basin and Ocean Plans, are summarized in Table 5. Maps illustrating the locations and types of potential beneficial uses along the San Francisco shoreline are shown in Figures 7 and 8.

Table 5. BENEFICIAL USES OF SURFACE WATERS, BASIN AND OCEAN PLANS

Surface waters	IND	PROC	NAV	REC-1	REC-2	COMM	ASBS	WILD	RARE	MAR	MIGR	SPAWN	SHELL
Pacific Ocean	●	-	●	●	●	●	●	●	●	●	●	●	●
San Francisco Bay													
Central	●	●	●	●	●	●	o	●	●	●	●	●	●
Lower	●	-	●	●	●	●	o	●	●	●	●	o	●
South	●	-	●	●	●	●	●	●	●	●	●	o	●

Note: o = potential beneficial use; ● = existing beneficial use.

IND = industrial service supply
PROC = industrial process supply
NAV = navigation
REC-1 = water contact recreation
REC-2 = nonwater contact recreation
COMM = ocean commercial and sport fishing
ASBS = areas special biological significance
WILD = wildlife habitat
RARE = rare and endangered species
MAR = marine habitat
MIGR = fish migration
SPAWN = fish spawning
SHELL = shellfish harvesting

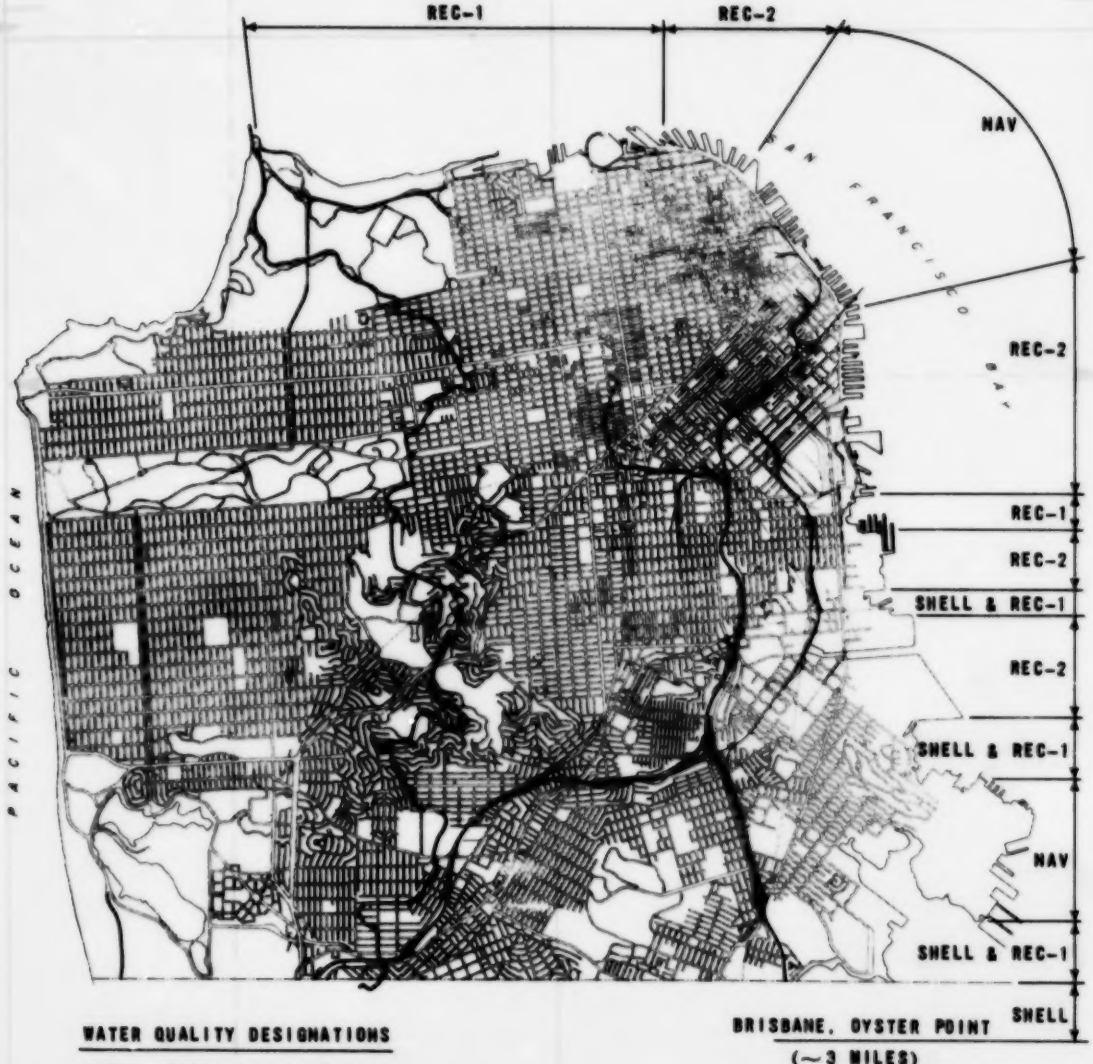


Figure 7. Potential bay beneficial use water quality summary.

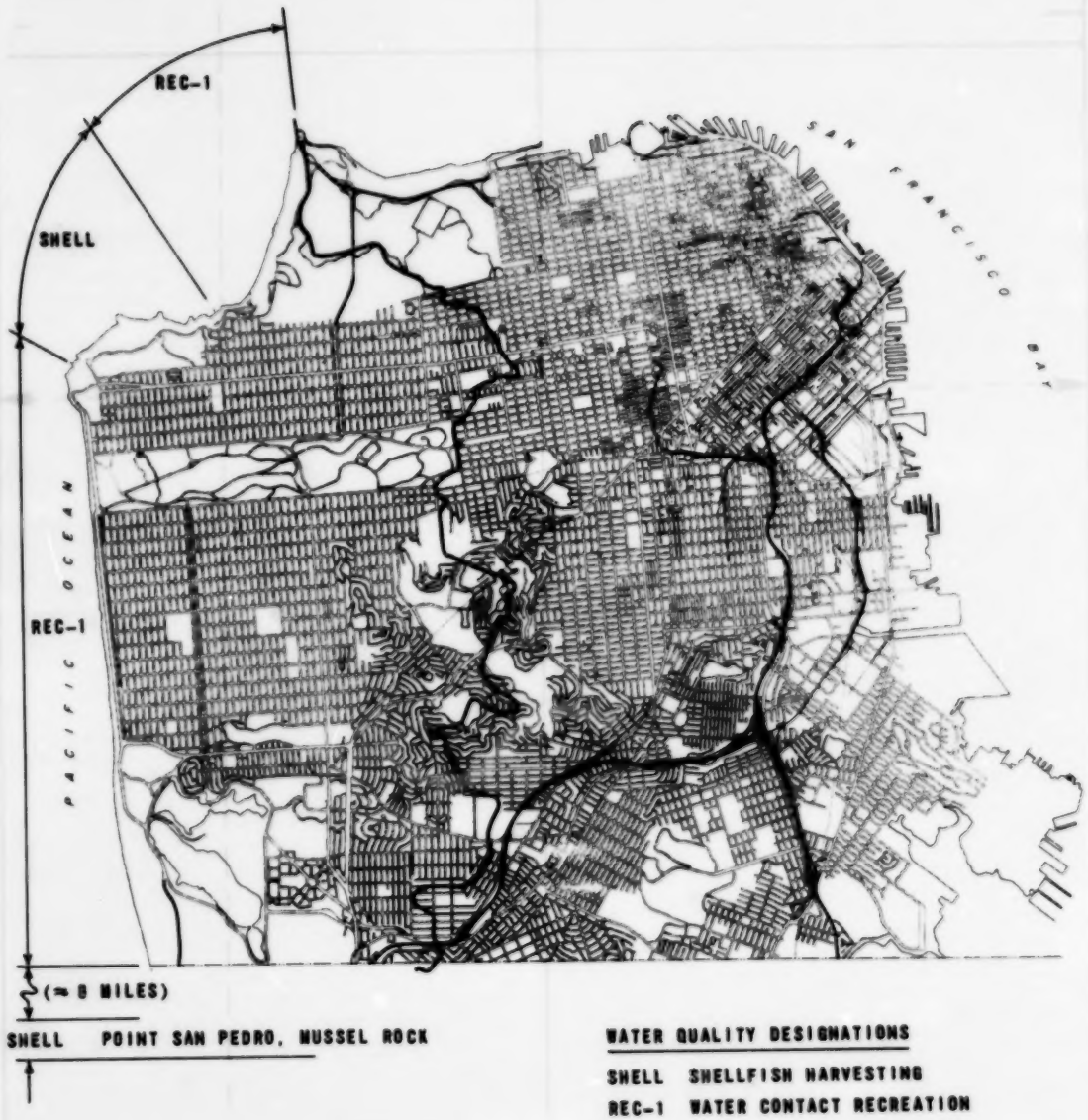


Figure 8. Potential ocean beneficial use water quality summary.

The water contact recreation and shellfish coliform standards of the Bay and Ocean Plans are summarized in Table 6. The RWQCB has stated that water contact criteria should apply to all bay and ocean waters. The higher water standard is only necessary near shellfish beds.

Table 6. SUMMARY OF COLIFORM STANDARDS
MPN/100 mL

	Water quality not to exceed	
	Shellfish	Water contact
Basin Plan		
Total coliforms		
30-day median	70	--
10% of samples over 30 days	230	--
5-day median	--	240
Maximum event	--	10,000
Fecal coliforms		
Median	--	50
Maximum event	--	400
Ocean Plan		
Total coliforms		
Median	70	--
10% of samples	230	--
Water samples	--	1,000
20% of samples over 30 days	--	1,000
Single event repeatable within 48 hours	--	10,000
Fecal coliforms		
30-day log median	--	200
10% of samples over 30 days	--	400

The Basin Plan states either bay or ocean discharge of treated wastewater effluent is acceptable but prefers an ocean discharge based on the following reasons:

1. ...an ocean discharge will provide a higher degree of protection due to its greater dilution potential.

2. The beneficial use of the Bay is more intensive than that of the offshore ocean area.

3. The likelihood of increased levels of treatment being required is less for the ocean than for the Bay.

4. During certain periods of the year, there is a net southern movement of water into the southern reach of San Francisco Bay, particularly on the west side of the Bay. This phenomenon would serve to move wastewater discharged by San Francisco into southern San Francisco Bay and to increase the residence time of that wastewater in the Bay. On the other hand, currents in the ocean

will generally serve to carry wastes from a properly designed ocean discharge in a southwesterly direction, away from the areas of critical concern.

5. It is the position of the State Department of Fish and Game that an ocean outfall is preferable to Bay discharge [2].

NPDES Permits

The RWQCB, by state law, processes and issues waste discharge requirements or NPDES permits. NPDES permits list receiving water beneficial uses, discharge limitations, and receiving water limitations. San Francisco has been issued two sets of NPDES permits: (1) wet-weather overflow permits and (2) treatment plant permits.

The wet-weather overflow permits have had a significant impact on the development of the master plan for San Francisco. These permits limit the allowed annual number of combined sewage overflows. The permits, summarized in Table 7, reflect a progression of changes. The first permits, issued in 1976, were very stringent, permitting an annual average of one or four overflow events per district or sewerage zone. These original overflow levels were relaxed to the values shown in Table 7 upon petition to the RWQCB by the city, November 1978 to June 1979.

Table 7. SUMMARY OF WET-WEATHER NPDES PERMITS

	North Point sewerage zone	Southeast sewerage zone	Richmond-Sunset sewerage zone	Southwest WPCP
Discharge prohibited	To areas with less that 10:1 initial dilution	To areas with less that 10:1 initial dilution	To areas with less than 10:1 initial dilution	Within 1,000 ft of shoreline With less than 100:1 initial dilution in dry weather With less than 25:1 initial dilution in wet weather
Overflow frequency limitations (allowable overflow events per year)	4	10 for Central and Islais basins 1 for India Basin and south	8	--

The treatment plant NPDES permits issued through 1977 required secondary treatment of all dry-weather flows and a "...properly designed and well-operated chemically assisted primary treatment process or other more cost-effective process" for wet-weather flows [3]. These treatment levels are based on PL 92-500 and the adopted Basin Plan.

The Clean Water Act of 1977 (PL 95-217) amended PL 92-500 to allow a modification of secondary treatment requirements for municipal works discharging into deep ocean waters. This act permits applicants to file for a modification to less than secondary treatment provided the discharge meets

specific requirements outlined in PL 95-217, and the SWRCB concurs. The act also authorizes the EPA to issue and enforce NPDES permits modifying secondary treatment requirements if the applicant:

- Discharges into certain ocean and estuarine waters
- Demonstrates, to the satisfaction of the EPA administrator, that the modification will not increase the discharge of toxic pollutants or otherwise impair the integrity of the receiving waters.

The acceptable minimum level of treatment for which a waiver may be granted is primary.* In accordance with PL 95-217, in September 1979, the city filed a request for a waiver of the secondary treatment requirement for the proposed Southwest plant for dry-weather flows from the Westside District and citywide wet-weather flows [4]. (Subsequently, the USEPA indicated that a waiver for citywide wet-weather flows would not be required.)

*On May 7, 1981, the U.S. Court of Appeals for the District of Columbia's Circuit voided this limitation. Cases No. 79-1639, 79-1934, 79-1935, and 79-2360 - Petitions for Review of Orders of the Environmental Protection Agency.

SECTION 4

MASTER PLAN DEVELOPMENT AND SELECTION

The development and selection of the master plan is discussed in this section. The section is divided into discussions on current wastewater management projects and development and selection of the proposed master plan configuration. A selected chronology of the Master Plan development in response to regulatory, technical, and citizen participation activities is summarized in Table 8. These interactions are paramount in the ultimate shaping and refining of such massively scoped, public works projects.

CURRENT WASTEWATER MANAGEMENT PROJECTS

In September 1971, the San Francisco Department of Public Works prepared the San Francisco Master Plan, which presented a program for the management of wastewater flows for the city. The primary objectives were to (1) upgrade the city's wastewater treatment level, and (2) to reduce the frequency and volume of wet-weather overflows.

The 1971 Master Plan concept provided for a single treatment plant on the west side at the Lake Merced site (adjoining San Francisco Zoo) to treat both dry- and wet-weather flows from the entire city. Dry-weather flows would receive secondary treatment; wet-weather flows would receive primary or chemically assisted primary treatment. Treated effluents would be discharged to the ocean through a new outfall. Sludge generated at this plant would be transported via a crosstown conveyance system to the existing Southeast plant for treatment and disposal. A 1973 amendment to the Master Plan provided the option of treatment of all bayside dry-weather flows at a second dry-weather plant on the bayside.

To control wet-weather overflows, the plan provided for system storage augmentation and the consolidation of overflow points. Shoreline and upstream retention basins would store excess wet-weather flow. Transport/storage facilities would transport the wet-weather flow to the plant on the west side for treatment and disposal. A schematic of this concept is shown in Figure 9.

Several studies have been undertaken since 1971 on the management of wastewater flows in San Francisco. Although other wet-weather flow routing alternatives have been proposed, the long-term objectives represented by the 1971 Master Plan, with the principal exception of substituting shoreline storage-transport interceptors for dispersed retention basins, have not changed. The amended 1971 Master Plan concept of two dry-weather plants, one for each side of the city, was accepted early although the question of bayside effluent discharge (into the bay or ocean) was not resolved.

Table 8. CHRONOLOGY OF MASTER PLAN DEVELOPMENT

Year	Regulatory actions	Implementation actions	Approvals/citizen participation
1949	California adopts first major water quality control legislation (creating water pollution control boards).	--	Approved by statewide electorate.
1965	Federal Water Pollution Control Act adopted.	--	--
1967	Regional board (RWQCB) prescribes requirements for San Francisco wet- and dry-weather discharges, calls for city to adopt Wastewater Master Plan by June 1971.	--	--
1968	--	San Francisco Department of Public Works (DPW) commences engineering studies.	San Francisco Board of Supervisors approves RWQCB resolution and declares its intent to comply.
1970	RWQCB prescribes building permit ban for San Francisco waste discharge violations. RWQCB lifts building ban after 60 days.	DPW initiates design for improved North Point outfall (largest city plant). First tunnel evaluation completed.	State electorate approves $250 million bond issue to provide Clean Water grants up to 12.5% of eligible costs.
1971	--	DPW issues Wastewater Master Plan featuring storage in upstream retention basins and tunnels, treatment in a new facility in the Southwest District, and ocean discharge. DPW implements innovative dissolved air flotation demonstration project with USEPA for wet-weather treatment as alternative to large central plant.	City initiates hearings on Master Plan to consider adoption.
1972	Federal Water Pollution Control Act Amendments passed. USEPA initiates EIS on Master Plan. USEPA denies waiver request for North Point plant. California adopts new ocean discharge policy with strict standards for toxics. USEPA notifies city that grant funds will be withheld until a city Wastewater Master Plan is approved.	City requests waiver of 85% BOD removal requirement for North Point (primary) plant. City submits application for upstream retention basin demonstration grant. City submits project report to state recommending ocean discharge for all treated discharges.	San Francisco Recreation and Parks Commission approves Master Plan in principle. San Francisco Board of Supervisors establishes Citizens Committee for public participation in Master Plan evaluation. San Francisco City Planning Commission approves basic concepts of Master Plan.
1973	USEPA denies upstream retention basin application due to lack of funds.	First independent review of Master Plan completed. DPW issues Supplement 1 to Master Plan recommending phased construction with immediate priority on dry-weather projects (to meet funding constraints and 1977 deadline for secondary treatment) through an expanded Southeast plant. City applies for NPDES permits.	San Francisco Board of Supervisors approves Supplement 1 to Master Plan. 1973-1974 citizens support program objectives and focus main concerns on neighborhood disruptions associated with upstream retention basins.
1974	USEPA complete EIS on Master Plan. RWQCB issues NPDES permits for the city's three dry-weather plants.	DPW completes pilot plant studies of alternative dry-weather treatment systems.	Final EIR (jointly with EIS) on Master Plan issued and approved. State electorate approves second $250 million Clean Water bond issue.

Table 8 (Continued)

Year	Regulatory actions	Implementation actions	Approvals/citizen participation
1975	RWQCB adopts Water Quality Control Plan, San Francisco Bay Basin (incorporating city's Master Plan concepts). Impounded federal pollution control funds released. State Board (SWRCB) initiates accelerated construction program policy.	DPW issues Overview Facilities Plan as prerequisite to project element grant funding. City adopts transport/storage concept over retention basins as more cost effective, less disruptive to the community, and consistent with accelerated construction objectives.	City electorate approves joint use concept for Southwest WPCP site development. San Francisco Technical Advisory Board unanimously endorses ocean over bay discharge for long-term solution. San Francisco Board of Supervisors reaffirms Master Plan.
1976	RWQCB issues tentative NPDES permit for new Southwest plant prescribing an equivalent of secondary treatment for dry-weather flow and chemically assisted primary (CAPS) for wet-weather flows. RWQCB issues NPDES permits for principal diversion structures prescribing stringent overflow limitations (one per year in west and north, four in east, with potential for more restrictive limits in future).	DPW implements bayside dry-weather design and construction. DPW implements design and construction of certain bayside wet-weather consolidation projects. DPW initiates design only of Westside storage/transport and ocean outfall.	City electorate authorizes $240 million wastewater program bond issue by strong margin, providing local share funding for a projected $1.5 billion program. Zoo Master Plan allowing joint use of expansion area with Southwest plant adopted by City Recreation and Park Commission.
1977	RWQCB updates NPDES permits for dry-weather plants. Clean Water Act of 1977 passed permitting qualifying marine dischargers to apply for waiver of secondary treatment.	DPW authorizes reevaluation of Master Plan through Southwest Facilities Plan project. City adopts sewer service charge method of financing as prescribed by law.	1975-1977: eight project element final EIRs issued, hearings held, and approvals given. Federal Clean Water act authorizes $24.5 billion in Clean Water grants distributed over 5 year period, 1978-1982.
1978	SWRCB adopts amendments to Ocean Plan (permitting less than secondary treatment and allowing initial dilution calculations in setting effluent standards for toxics). RWQCB approves relaxation of overflow limitations from one to four per year for North Shore District.	Through 1977, approximately $160 million in Master Plan implementation projects under construction. DPW releases Southwest Interim Report. Findings again support basic Master Plan concepts and projects inflated total cost at $1.9 billion with a further increase of $150 million for each year's delay of major projects. City files first of three reports seeking relief from stringent overflow limitations with RWQCB. DPW completes pilot plant studies of alternative wet-weather treatment systems and wet-weather forcing of dry-weather processes. City files preliminary waiver application based on total ocean discharge. Proposes primary treatment of Westside dry-weather flows blended with secondary treated bayside flows. City awards Southeast plant expansion and additional North Shore consolidation construction projects raising total implementation commitment to $330 million.	State electorate approves third Clean Water bond issue for $365 million. Hearings on sewer service charges alert citizens to a realization of local cost impacts. Citizen groups support city's applications for relief from stringent standards. Regional Coastal Commission denies approval of Westside transport project over concern for potential accelerated beach erosion.

Table 8 (Concluded)

Year	Regulatory actions	Implementation actions	Approvals/citizen participation
1979	USEPA, Region IX, advises city it would be appropriate to apply for secondary treatment waiver for both wet-weather and dry-weather plants. RWQCB approves relaxation of overflow limitations from one to eight per year for Westside and sets limits of ten (commercial shipping area) and one (potential shellfish area) for remaining bayside areas. USEPA, Headquarters, advises city that CSO treatment facilities do not fall under requirement for secondary treatment for all publicly owned treatment works, reversing earlier Regional Council findings. RWQCB initiates cease-and-desist order hearings on program delays.	City files second and third reports seeking relaxation of overflow standards with RWQCB. DPW issues final draft Southwest Facilities Plan. City files final waiver application, seeking primary treatment of excess wet-weather flows in addition to blended secondary and primary treatment of dry-weather flows, again based on total ocean discharge. City authorizes planning of final program elements. City initiates filing for amended NPDES permit to allow primary treatment for excess wet-weather flows. City raises implementation commitment to $375 million.	State Coastal Commission, on appeal, approves Westside projects subject to strict mitigation measures including beach sand replenishment program, if necessary. EIR on Southwest Facilities Plan receives San Francisco Planning Commission approval. San Francisco Board of Supervisors denies DPW request to increase sewer service charge. San Francisco Board of Supervisors authorizes Budget Analyst review of complete Wastewater Program and places freeze on new contracts. San Francisco Chief Administrative Officer commissions second independent engineering review of project.
1980	General Accounting Office issues report to Congress recommending more flexibility in water quality goals to reduce costly large construction projects to correct combined sewer overflows. RWQCB issues amended NPDES permit allowing primary treatment for excess wet-weather flows subject to SWRCB granting Ocean Plan exemption and USEPA approval. SWRCB approves exemption request. SWRCB adopts ocean discharge policy setting low funding priority for secondary treatment without demonstrated need. USEPA implements 3 month grant funding freeze.	City files for exemption of Ocean Plan requirement for 75% total suspended solids removal for excess wet-weather flows. Concern over funding availability at all levels leads city to adopt carefully structured staged implementation approach to ensure operable systems in the event of funding curtailment and to minimize cost. City raises implementation commitment to $450 million and fixes first system-wide implementation plateau cost at $1.6 billion. Will provide for ocean discharge of all dry-weather flows and Southeast and Westside wet-weather flows with interim bay discharge of North Point wet-weather flows.	San Francisco Board of Supervisors authorizes third independent review of program by "Blue Ribbon" panel. San Francisco Board of Supervisors approves Southwest Facilities Plan releasing freeze on wastewater projects. San Francisco citizens' group introduces ballot measure to again freeze city funds. Ballot measure overwhelmingly defeated.

Figure 9. 1971 Master Plan for wet-weather wastewater flow management.

The Southeast WPCP would be expanded and upgraded to provide secondary treatment for all bayside dry-weather flows. A new secondary dry-weather plant for west side flows would be constructed on the Lake Merced site. By undergrounding portions of this plant, the adjacent zoo could expand, permitting dual use of the site and conserving irreplaceable open space.

Overflow reduction would be accomplished through increased treatment capacity and the provision of storage with the consolidation of overflow structures (outfalls) along the city's shoreline. Large structures constructed ahead of the overflow points would hold the combined wastewater during wet weather until treatment capacity was available. At that time, these stored flows would be conveyed to the treatment facilities by transport conduits and pump stations. If the wastewater flow exceeded the combined storage and treatment capacities, the excess flow would be discharged through a reduced number of overflow structures to the receiving waters.

Based on these concepts, the city committed itself to a number of wastewater management projects, now currently under construction or completed. These projects provide for the secondary treatment of all bayside dry-weather flows, and reduction in the number of untreated bayside wet-weather overflows into the bay. The projects are as follows:

- Expanded primary and high purity oxygen activated sludge facilities at the existing Southeast WPCP to treat all bayside dry-weather flows.

- Two force mains, in series, from the North Point WPCP to the expanded Southeast WPCP to transport North Shore dry-weather flows to the Southeast WPCP.

- Two pump stations, one near the existing North Point WPCP and the second at Channel Street, to convey dry-weather flow to the Southeast WPCP.

- North Shore outfalls consolidation.

- Channel outfalls consolidation.

- Islais Creek outfalls consolidation, specifically the south side of Islais Creek.

Locations of these projects are shown in Figure 10 and selected construction photographs in Figure 11. The photographs emphasize the enormous physical and financial scale of the project.

Through 1977, Master Plan construction on the west side of the city had been limited to interim improvements to the 40 year old Richmond-Sunset primary treatment plant. Three projects, however, which would form a core of the contemplated west side system, were under advanced stages of final design: the Westside transport, the Westside Pump Station, and the Southwest Ocean Outfall. The Westside Transport was designed to convey all west side flows to the Westside Pump Station. This pump station would pump these flows to

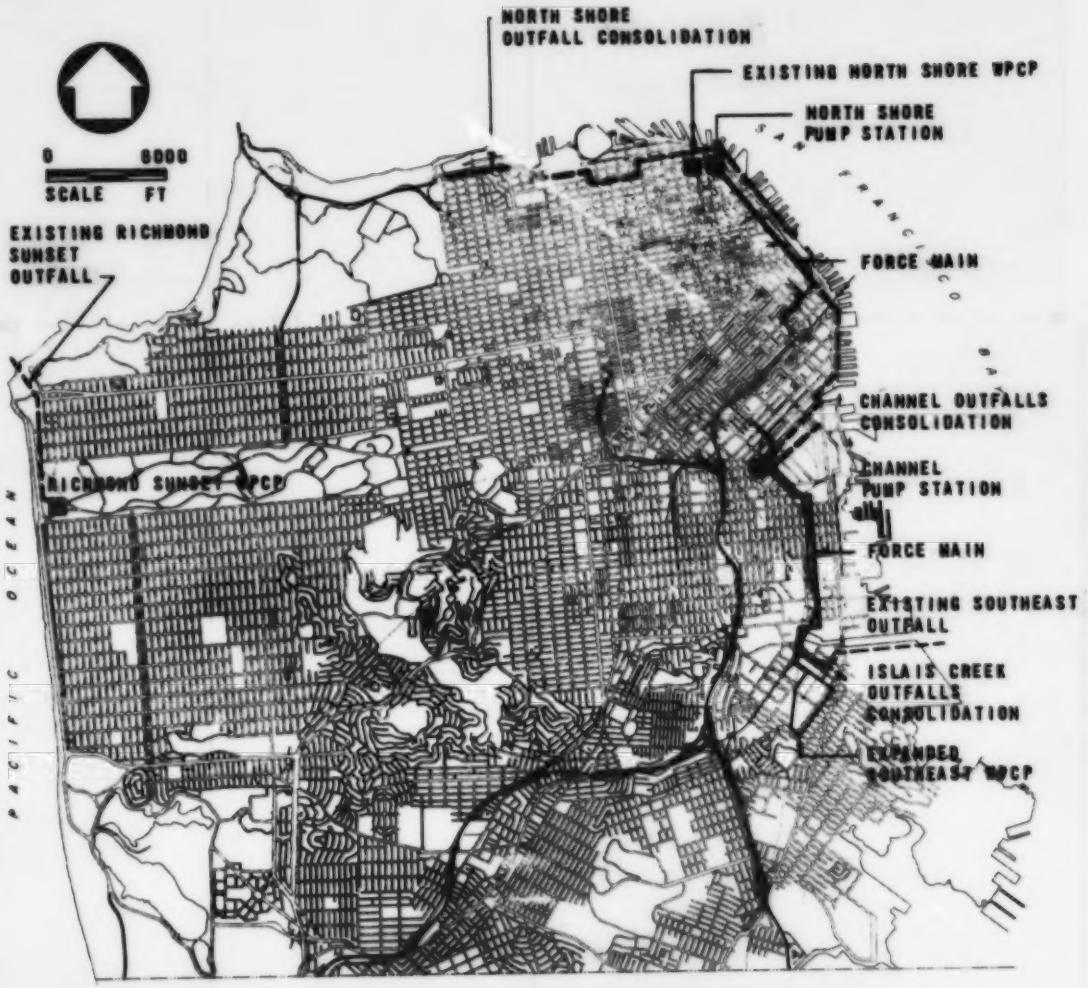
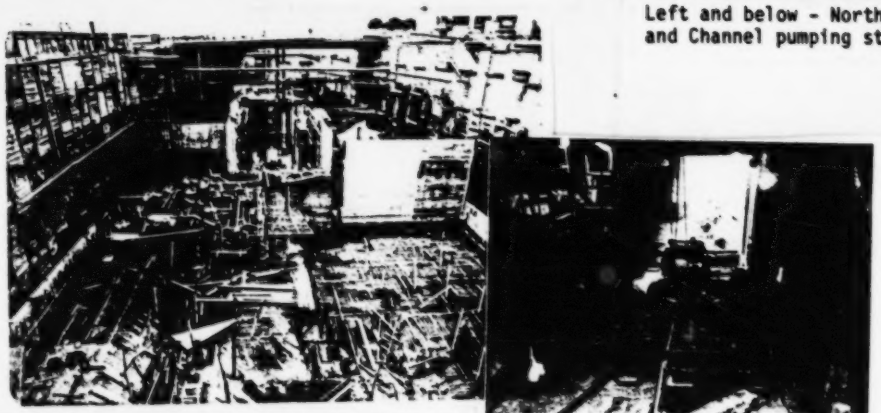


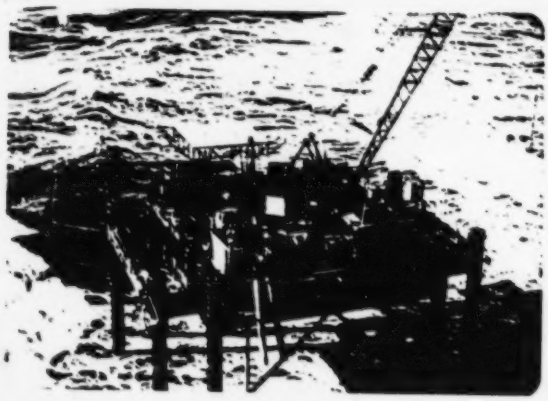
Figure 10. Wastewater flow management facilities currently under construction.

Above, left and right - Channel and North Shore outfall consolidation projects apply storage/ transport concept. Temporary railroad accelerates tunnel spoils removal.

Left and below - North Shore and Channel pumping stations.



Below - Mobile exploration platform "Spider 2" assists in outfall geotechnical survey through turbulent surf zone.



Photographs courtesy of San Francisco Clean Water Program Department of Government and Public Affairs.

Figure 11. Construction photographs, San Francisco Clean Water Program.

the proposed treatment plant on the west side. Although the questions of citywide wet-weather flow treatment and bayside effluent discharge had not been resolved, the city, under regulatory agency directive, authorized the design of a three-barrel Southwest Ocean Outfall. As initially designed, this outfall would discharge citywide wet-weather effluent through two conduits and combined bayside and westside dry-weather effluent through the third conduit into the Pacific Ocean. Subsequent project staging and engineering/economic considerations, discussed in Section 6, led to the adoption of a single barrel system.

SYSTEM CONFIGURATION DEVELOPMENT AND SELECTION

As noted, the basic dry-weather flow routing, treatment, and discharge had been resolved with the exception of the question of discharge of bayside dry-weather flows. The discussion on system configuration concentrates on the development of wet-weather flow routing alternatives.

The basic planning units of the wet-weather alternatives are the subareas of the three major watersheds. This planning concept allows flows to be collected and routed to common points. Systemwide alternatives are easily developed since the decision to transport a subarea's flows to a second subarea implies either the flows are treated and discharged from the second subarea or transported again with the second subarea's flows to a third subarea. Four potential master plan flow routings with options were developed in this manner. These master plans ranged from a six plant system to a consolidated single plant system for treatment of wet-weather flows and included ocean and/or bay discharge. Diagrams of these master plans are illustrated in Figures 12 and 13.

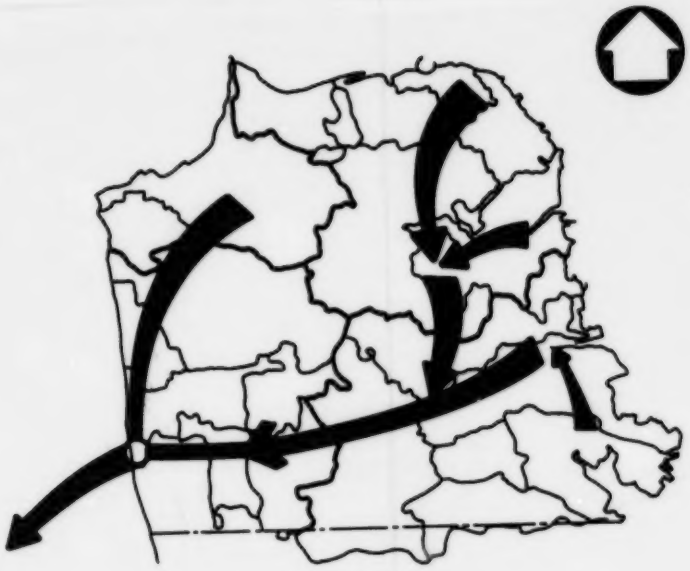
Special studies were done on storage/transport, crosstown tunnel alignments and costs, and plant sitings to identify constraints, advantages, and associated storage and treatment capacities.

Use of the computer model, SFMAC [1], provided the means for processing the information required for technical analysis of the alternative plans. The objective of the analysis was to ascertain the combinations of facilities (routings, capacities, locations) that would produce overflow reductions in compliance with requirements promulgated by the RWQCB or to provide a technical basis for amending these requirements.

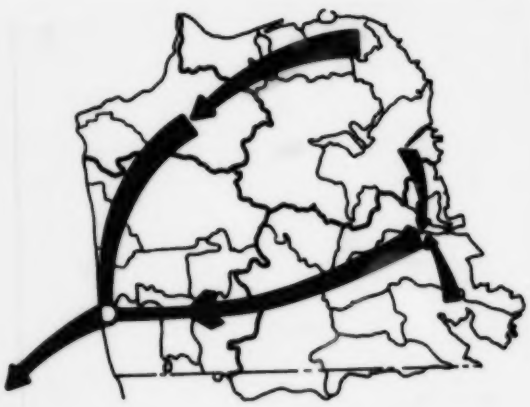
The pumping, storage, and treatment capacities of each master plan for three overflow frequency levels (one, two, and four overflows per year) were developed using SFMAC. In all, 38 alternatives were initially developed in an effort to find the optimal sizes for the various components of each master plan system.

Reduction from Thirty-Eight to Five Alternatives

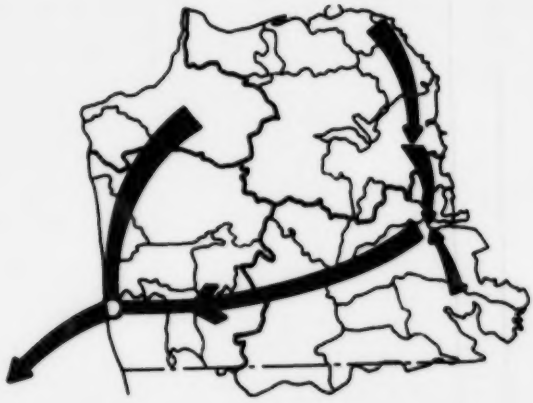
The 38 alternatives were reduced to 5 on the basis of engineering, economic, and environmental factors [5].



MASTER 1
HIGH LEVEL BAYSIDE
(1971 MASTER PLAN)



MASTER 1A
DUAL CROSSING



MASTER 1B
LOW LEVEL BAYSIDE

Figure 12. Master Alternative 1 with variations, ocean discharge.

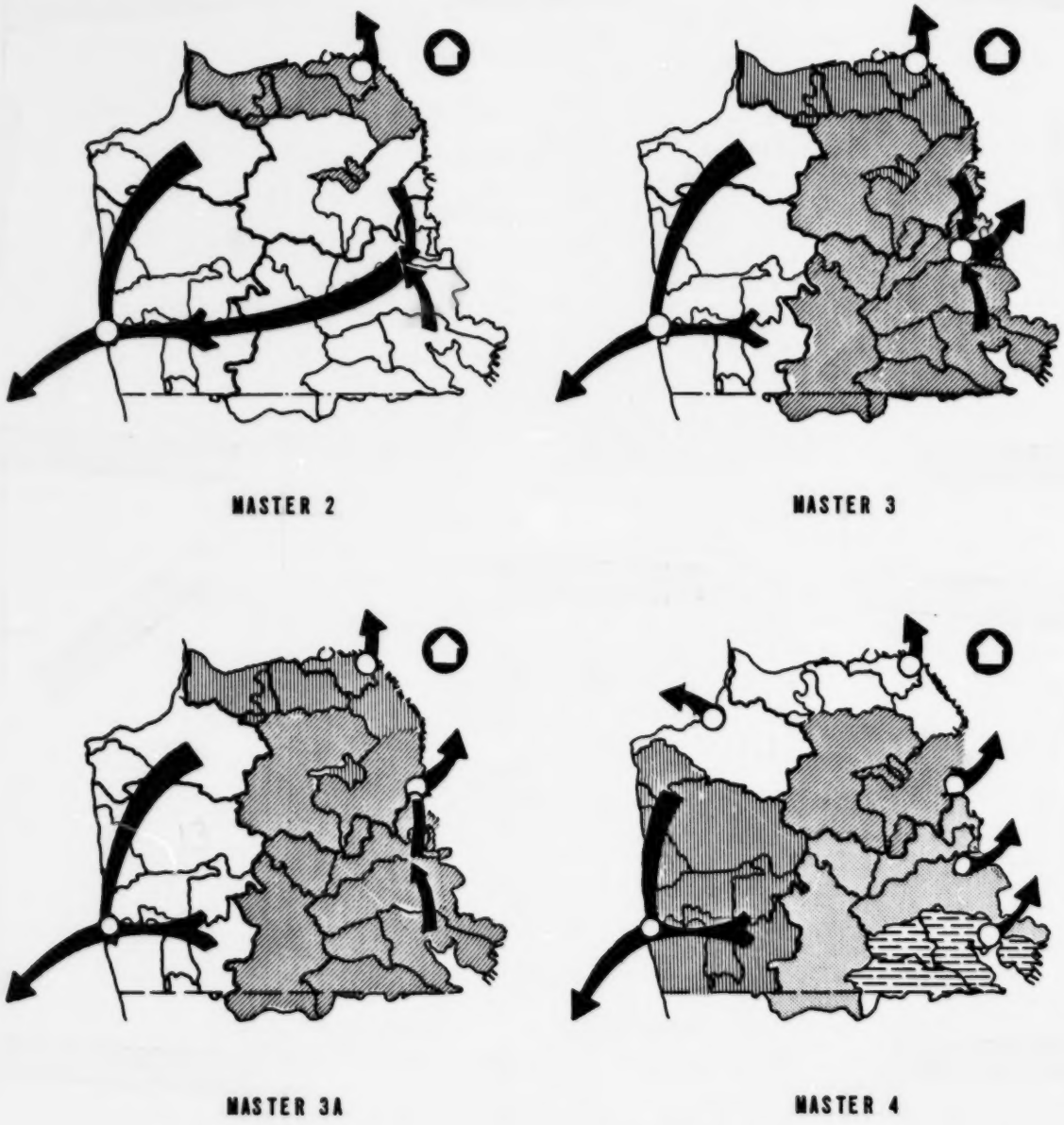


Figure 13. Master Alternatives 2, 3, and 4 with variations.

The alternatives of Master Plans 1B and 3 were chosen for further development. Master Plan 1B offered higher receiving water quality benefits and lower operation and maintenance costs than the other master plans.

Master Plan 3 provided less receiving water quality benefits than Master Plan 1B because of continued discharge of effluent to the bay. The alternatives of Master Plan 3, however, were lowest in first (capital) costs and offered a potentially effective systemwide combined sewer overflow control plan without the crosstown tunnel.

The alternatives of Master Plans 2 and 4, as well as the other options of Master Plans 1 and 3, were eliminated for economic, water quality, and operational reasons. The alternatives with dual tunnel crossings were dropped due to public opposition.

In September 1978, following reviews with city, state, and RWQCB representatives, it was recommended that Master Plan 1B alternatives at one, four, and eight overflows per year be carried forward. It was further recommended that the Master Plan 3 alternatives at one and four overflows per year also be carried forward. These five alternatives not only covered the range of overflow frequency levels that were considered feasible (existing NPDES permits specified one or four overflows at this time), but also included the major options of single or multiple wet-weather treatment locations and bay or ocean discharge of wastewater from San Francisco.

Reduction from Five Alternatives to One Alternative

The basic differences between the two selected master alternatives were the points of discharge, the number of wet-weather treatment plants, and the interbasin conveyance facilities. For an equivalent level of overflow protection, the aggregate storage volumes and excess flow treatment rates were approximately the same. Representative cost data for the five alternatives are shown in Table 9. Master Plan 1B provided lower operation and maintenance costs by having a single treatment facility for excess wet-weather flows, but at a higher capital cost due to increased conveyance requirements. (In all alternatives, dry-weather plants were assumed to operate at their maximum effective capacities during wet weather with the excess flows treated in a new or expanded facility.) Conversely, by treating and discharging excess flows locally, Master 3 alternatives reduced capital costs as a tradeoff to higher operation and maintenance. Of the three required treatment facilities under Master 3, one would be a renovated existing plant (North Point WPCP).

The assumed wet-weather treatment process was chemically assisted primary sedimentation with chlorination and dechlorination of effluent discharge to the bay. High purity oxygen activated sludge was the assumed secondary treatment for dry-weather flows with chlorination and dechlorination of effluent discharged to the bay. Simulated ocean discharges were found to meet shoreline bacterial standards without chlorination, thus providing an added operational cost advantage to Master 1B alternatives.

Sludge generated in both master plans would be transported to the Southeast WPCP for treatment and disposal. In Master Plan 1B, sludge from Southwest WPCP would be pumped through pipelines in the crosstown tunnel; in Master Plan 3, this sludge would be pumped to Southeast WPCP through a surface pipeline.

Table 9. COST ESTIMATES OF FIVE ALTERNATIVES
Millions of Dollars, ENR 4000

		Wet weather		Dry weather		Total	
Alternatives	Overflows/yr	Capital	Annual operation and maintenance	Capital	Annual operation and maintenance	Capital	Annual operation and maintenance
Master Plan 1B							
1	1	1,348.1	3.75	453.6	17.29	1,801.7	21.04
2	4	1,115.3	3.42	451.5	17.29	1,606.8	20.71
3	8	963.5	2.65	448.6	17.29	1,413.1	19.95
Master Plan 3							
4	1	1,229.0	5.70	475.6	17.85	1,704.6	23.55
5	4	1,051.8	5.11	469.8	17.84	1,521.6	22.95

The evaluation and selection process of reducing the five alternatives to one involved the following series of steps:

- Determination of evaluation factors and the relative ranking of these factors
- Comparative ranking of the alternatives with respect to each factor
- Discussion of the relative advantages and disadvantages of each alternative and the tradeoff considerations resulting in the selection of the apparent best alternative.

Fifteen evaluation factors divided into three groups (cost, environmental/social, and engineering) were selected and assigned weights relative to each other within their group. The factors, groups, and relative weights are listed in Table 10.

To provide a background for the ranking of alternatives, the relative advantages and disadvantages of the alternatives were summarized. Then the alternatives were ranked with respect to the three groups of factors. The highest ranked alternative in each group was identified in this process. The final step in the process was a discussion of the tradeoffs of each alternative which resulted in the selection of the apparent best alternative.

Cost Ranking--

The ranking of the five alternatives with respect to cost factors is shown in Table 11. The alternative with the lowest sewer service charge, lowest

operation and maintenance cost, lowest capital cost, and easiest implementation received the highest ranking. Alternative 3 is the best cost alternative followed by Alternative 2.

Table 10. WEIGHTING OF EVALUATION FACTORS

Factor	Relative weight
Cost	
Sewer service charge	10
Operation and maintenance	6
Capital	4
Implementability	2
Environmental/social	
Environmental impact	10
Public acceptability	7
Compatibility with local planning	5
Social impact	2
Land use	2
Scarce resources	1
Engineering	
Water quality impact	10
Reliability and flexibility	8
Bypass analysis	3
Reclamation potential	1
Flood protection	1

Table 11. RANKING OF ALTERNATIVES - COST FACTORS

Factor	Relative weight	Alternative				
		1	2	3	4	5
Sewer service charge	10	2/20	4/40	5/50	1/10	3/30
Operation and maintenance	6	3/18	4/24	5/30	1/6	2/12
Capital	4	1/4	3/12	5/20	2/8	4/16
Implementability	2	5/10	5/10	5/10	3/6	3/6
Total		52	86	110	30	64

Note: Table numerical values: highest number represents highest rating.

1/2 = rating/(rating x relative weight).

Environmental/Social Ranking--

The ranking of alternatives with respect to environmental/social factors is shown in Table 12. These factors cannot be quantified and are not numerically weighted.

Table 12. RANKING OF ALTERNATIVES - ENVIRONMENTAL/SOCIAL FACTORS

Factor	Relative weight	Alternative 1	2	3	4	5
Environmental impact	10	++	+	+	-	-
Public acceptability	7	0	0	0	-	-
Compatibility with local planning	5	+	+	+	-	-
Social impact	2	+	+	+	-	-
Land use	2	++	++	++	--	--
Scarce resources	1	-	0	0	+	+

Note: Ratings (highest to lowest): ++, +, 0, -, --,. Symbols are used because environmental/social factors do not lend themselves to quantitative characterization.

The environmental/social impacts of Master Plan 3 alternatives were projected to be greater than the impacts of Master Plan 1B alternatives. However, the latter did not exhibit major environmental/social differences among each other. Alternative 1 is ranked as the best environmental alternative. Alternatives 2 and 3, which ranked equal, are ranked slightly behind Alternative 1.

Engineering Ranking--

The ranking of alternatives with respect to engineering factors is presented in Table 13.

The water quality impact factor indicates the ability of each alternative to meet or exceed the discharge and receiving water quality criteria established by state and federal agencies. The ability to achieve goals established by the Basin Plan and to reduce the number of receiving water coliform violation days resulting from combined sewer overflows is also included in this factor.

All five alternatives conform with the water quality objectives and waste load restrictions presented in the Basin Plan. The Master Plan 1B alternatives also comply with the recommendation of ocean discharge of all wastewater flows; Master Plan 3 alternatives do not.

The five alternatives also comply with dry- and wet-weather initial dilution and receiving water quality limits. In addition, all of the alternatives will probably meet future NPDES dry-weather discharge permits assuming no waiver. They will also probably meet future NPDES wet-weather permits

assuming CAPS or primary treatment (waiver) with the possible exception of total suspended solids (TSS) effluent limits.

Table 13. RANKING OF ALTERNATIVES - ENGINEERING FACTORS

Factor	Relative weight	Alternative 1	2	3	4	5
Water quality impact	10	5/50	5/50	4/40	3/30	3/30
Reliability and flexibility	8	5/40	4/32	3/24	2/16	1/8
Bypass analysis	3	5/15	5/15	5/15	5/15	5/15
Reclamation potential	1	5/5	5/5	5/5	4/4	4/4
Flood protection	1	5/5	5/5	5/5	5/5	5/5
Total		115	107	89	70	62

Note: Table numerical values: highest number represents highest rating.

1/2 = rating/(rating x relative weight).

Selection of Wastewater Management Plan

A summary of the evaluation factor group rankings is shown in Table 14. Alternative 3 ranked highest from a cost standpoint and Alternative 1 ranked highest in environmental/social factors and engineering factors. Alternatives 4 and 5 were dropped at this point due to consistently lower rankings than the equivalent Master Plan 1B alternatives.

Table 14. SUMMARY OF EVALUATION FACTOR GROUP RANKINGS

Evaluation factor group	Alternative ranking 1	2	3	4	5
Cost	4	2	1	5	3
Environmental/social	1	2	2	4	4
Engineering	1	2	3	4	5

Note: Ranking: 1 = best; 5 = worst.

The selection process narrowed down to Alternatives 1, 2, and 3. A trade-off process was required to narrow the selection down to one alternative. This trade-off process included a marginal cost/benefit analysis and a risk analysis.

Marginal Cost/Benefit Analysis--

A comparison of the annual hours of overflow, volume of overflow, coliform violation days, BOD mass in overflow, and suspended solids (SS) mass in overflow for various annual overflow frequencies is shown in Table 15. The percent reductions from the existing condition for the categories listed at various annual overflow frequencies are listed in Table 16. The incremental costs for reductions in the categories in Table 16 and shown in Table 17.

Table 15. COMPARISON OF SEVERAL PARAMETERS FOR VARIOUS OVERFLOW FREQUENCIES

Parameter	No project condition[a]	Overflow frequency, events/yr			
		16	8	4	1
Wet-weather capital cost, $ x 10^6	141.0	832.4	963.5	1,155.3	1,348.1
Overflow					
Time, h/yr	319	56	31	14	3.5
Volume, Mgal/yr	6,161	2,634	1,361	496	158
Mass in overflow, 1,000 lb/yr					
BOD	3,465	1,075	542	180	55
SS	8,357	3,036	1,610	566	175
Coliform violation time[b], d/yr	197	94	70	37	10

a. "No project condition" includes completion of projects under construction at the time of the master plan review and selection. In the "no project condition," no additional projects would be undertaken.

b. Violation days are based on the most stringent body contact standards (30 day, 20 percentile >1,000 MPN/100 mL) for Westside and North Shore and on the corresponding most stringent shellfish standards (30 day, 10 percentile >230 MPN/100 mL) for Southeast. Recent RWQCB tentative discharge permits for the North Shore and Westside sewerage zones use a criterion of days greater than 1,000 MPN/100 mL.

Mgal/yr x 0.0438 = m^3/yr
lb/yr x 0.4536 = kg/yr

Table 16. COMPARISON OF REDUCTION PERCENTAGES FOR SEVERAL PARAMETERS FOR VARIOUS OVERFLOW FREQUENCIES

Parameter	No project condition	Reduction from existing condition, %			
		Overflow frequency, events/yr			
		16	8	4	1
Overflow					
Time, h/yr	319	82.5	90.3	95.6	98.9
Volume, Mgal/yr	6,161	57.3	77.9	92.0	97.4
Mass in overflow, 1,000 lb/yr					
BOD	3,465	69.0	84.4	94.8	98.4
SS	8,357	63.7	80.7	93.2	97.9
Coliform violation time, d/yr[a]	197	52.3	64.5	81.2	94.9

a. Violation days are based on the most stringent coliform body contact standards (30 day, 20 percentile >1,000 MPN/100 mL) for Westside and North Shore and on the corresponding most stringent shellfish standards (30 day, 10 percentile >230 MPN/100 mL) for Southeast. Recent RWQCB tentative discharge permits for the North Shore and Westside sewerage zones use a criterion of days greater than 1,000 MPN/100 mL.

Mgal/yr x 0.0438 = m^3/yr
lb/yr x 0.4536 = kg/yr

Table 17. COMPARISON OF INCREMENTAL CAPITAL COSTS FOR SEVERAL PARAMETERS FOR VARIOUS OVERFLOW FREQUENCIES

Annual overflow frequency	Incremental capital wet-weather cost, $ x 10^6	Overflow reduction		Mass reduction, $/lb		Coliform violation day reduction,[a] $ x 10^6/d
		Time, $ x 10^6/h	Volume, $ x 10^3/Mgal	BOD	SS	
No project condition	691.4	2.6	196.0	289.3	130.0	6.7
16	131.1	5.2	103.0	246.0	91.9	5.5
8	191.8	11.3	221.7	529.8	183.7	5.8
4	192.8	18.4	570.4	1,542.4	493.1	7.1
1						

a. Violation days are based on the most stringent coliform body contact standards (30 day, 20 percentile >1,000 MPN/100 mL) for Westside and North Shore and on the corresponding most stringent shellfish standards (30 day, 10 percentile >230 MPN/100 mL) for Southeast. Recent RWQCB tentative discharge permits for the North Shore and Westside Sewerage Zones use a criterion of days greater than 1,000 MPN/100 mL.

Mgal x 0.0438 = m^3
lb x 0.4536 = kg

The incremental costs for reducing overflow time, overflow volume, BOD mass in overflow, SS mass in overflow, and coliform violation days are the minimum for the 16 to 8 overflow range, as shown in Table 16. Generally, these incremental costs are substantially lower than any of the other incremental costs. Thus, in keeping with the EPA marginal cost criteria, it does not appear economical to try to reduce the number of annual overflows in San Francisco much below eight per year. This frequency is equivalent to that of Alternative 3. With the exception of violation day reduction, the marginal cost/unit benefit ratios of Alternative 1 range from four to eight times the minimums (for Alternative 3), thus ruling out Alternative 1 as uneconomical. Graphical representations of these data are shown in Figures 14 and 15.

Risk Assessment

Alternative 3 appeared to be the most favorable alternative, but there was a risk involved in selecting this alternative. Due to the review of NPDES permits and possible stricter treatment and discharge requirements in the future, the treatment and storage/transport systems in Alternative 3 could require new construction to meet the stricter requirements. While more expensive, Alternative 2 does have the capacity to meet future stricter requirements (i.e., one or four annual overflows). By selecting Alternative 3, the city would be taking a chance.

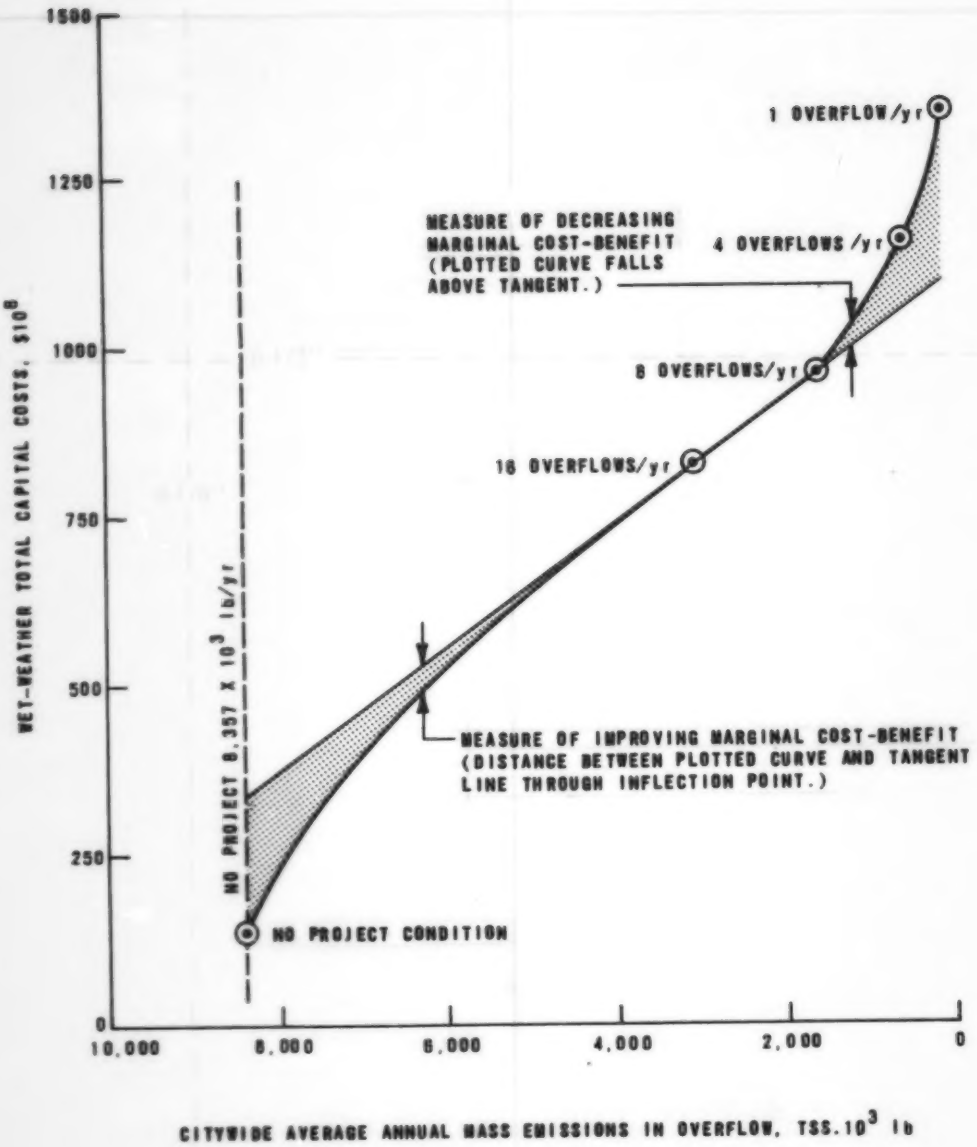
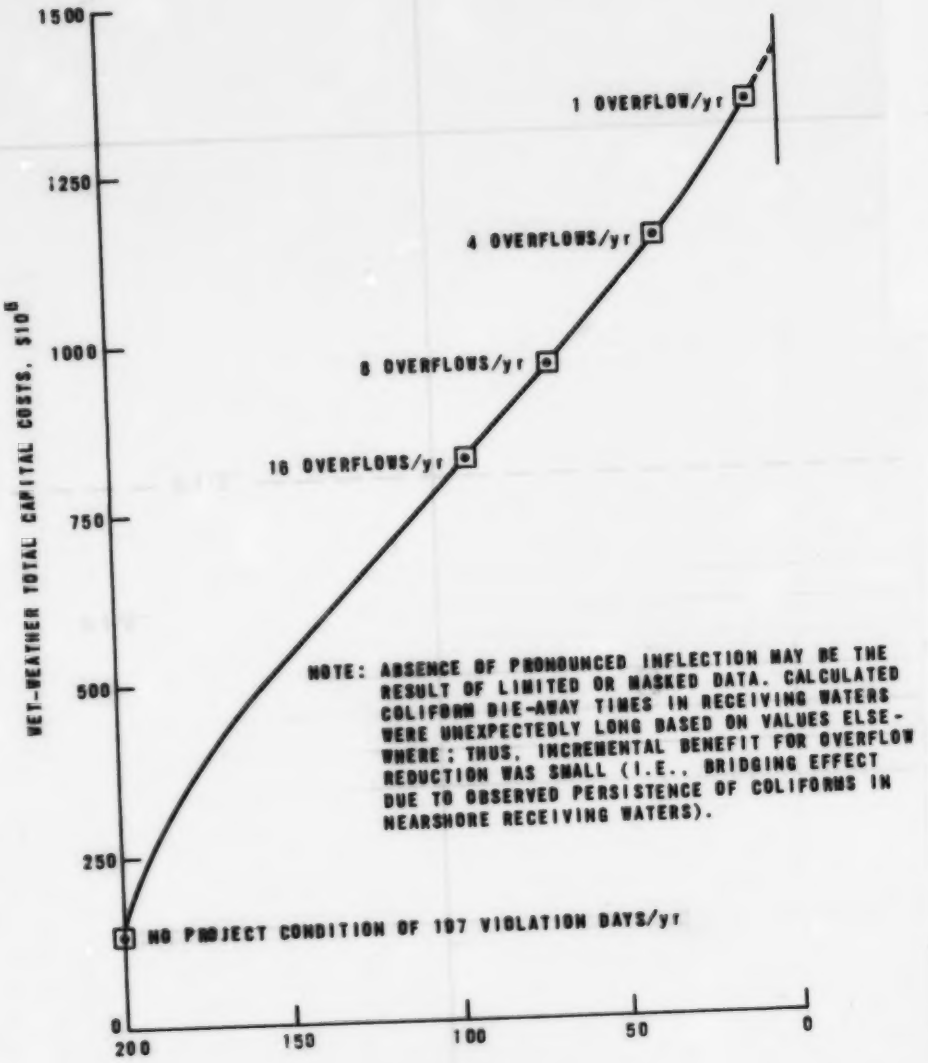


Figure 14. Overflow total suspended solids emissions versus wet-weather capital costs - Master Plan 1B.


1500
1250
1000
750
500
250
0
WET-WEATHER TOTAL CAPITAL COSTS, 10^6
1 OVERFLOW/yr
4 OVERFLOWS/yr
8 OVERFLOWS/yr
16 OVERFLOWS/yr
NOTE: ABSENCE OF PRONOUNCED INFLECTION MAY BE THE RESULT OF LIMITED OR MASKED DATA. CALCULATED COLIFORM DIE-AWAY TIMES IN RECEIVING WATERS WERE UNEXPECTEDLY LONG BASED ON VALUES ELSEWHERE; THUS, INCREMENTAL BENEFIT FOR OVERFLOW REDUCTION WAS SMALL (I.E., BRIDGING EFFECT DUE TO OBSERVED PERSISTENCE OF COLIFORMS IN NEARSHORE RECEIVING WATERS).
NO PROJECT CONDITION OF 197 VIOLATION DAYS/yr
200
150
100
50
0
CITYWIDE AVERAGE ANNUAL VIOLATION DAYS (MOST STRINGENT BODY CONTACT STANDARDS)[a]

a. BODY CONTACT 30-DAY, 20 PERCENTILE > 1000 MPN/100 mL FOR WESTSIDE AND NORTH SHORE. CORRESPONDING VALUES FOR SOUTHEAST ARE MOST STRINGENT SHELLFISH STANDARDS-30-DAY, 10 PERCENTILE > 230 MPN/100 mL.

Figure 15. Average annual coliform violation days versus wet-weather capital costs - Master Plan 1B (ENR 4000).

Conclusion

Based on available information, Alternative 3 represents the best compromise among the three groups of evaluation criteria. It ranked first in the cost evaluation, second in environmental/social, and third in engineering. A second economic evaluation, the marginal cost comparison, also showed Alternative 3 to be the most economical alternative. Alternative 3 consolidates the treatment of wet-weather flows at one site conforming to the 1971 San Francisco Master Plan and provides a combined sewer overflow control system that is operationally flexible and has maintenance reliability.

In the final selection process, eight overflow alternatives were also assessed in the Master 3 configuration for both two and three plant options; however, capital cost savings continued to be overshadowed by increased operation and maintenance costs.

SECTION 5

SELECTED COMBINED SEWER OVERFLOW CONTROL MASTER PLAN

The main feature of the selected master plan is the interception of citywide wet-weather flows and their conveyance to the Southwest WPCP for treatment prior to discharge through the Southwest Ocean Outfall. Because San Francisco has a combined sewer system, the transport and pumping facilities would be used to convey and pump both wet- and dry-weather flows, depending on the season. The combined wet- and dry-weather treated discharges to the ocean represent 97.5% of the total annual flows, the remainder escaping as overflows. Under the bay discharge alternatives, only 22.1% of citywide flows would have been discharged directly to the ocean. A description of the flow routing systems, planned level of treatment and performance, cost allocation and financing, and environmental/socioeconomic impacts is presented in the following paragraphs. Implementation priorities and design modifications adopted to meet reduced funding levels are described in Section 6.

FLOW ROUTING

Westside wet-weather flows would be collected by gravity in the Westside Transport that would intercept, store, and transport these flows to the Westside pump station, reducing the number of combined wastewater overflows on the Westside. This pump station would pump these flows to the wet-weather treatment facilities at the Southwest WPCP.

North Shore wet-weather flows would be conveyed by the North Shore Outfall Consolidation (NSOC) structures to the North Shore pump station where they would be pumped south to Islais Creek pump station. The Islais Creek pump station would pump all bayside wet-weather flows through the Crosstown Tunnel to the treatment facilities at the Southwest WPCP.

The treated Southwest WPCP wet-weather effluent would be discharged through two barrels of the Southwest Ocean Outfall 3 km (2 miles) offshore. The configuration and details of the wet-weather system are shown in Figure 16. The total storage provided would be 0.57×10^6 m^3 (150 Mgal) corresponding to less than 2% of the average annual runoff. Of the total storage, more than 20% would be developed from designed backwater within the existing system. The peak wet-weather treatment capacity would be 5.5 times the dry-weather average, 26 m^3/s versus 4.7 m^3/s (590 Mgal/d versus 107 Mgal/d).

The dry-weather system of the selected wastewater management plan has two treatment plants with effluent disposal through the third barrel of the Southwest Ocean Outfall 6 km (4 miles) offshore. The dry-weather facilities

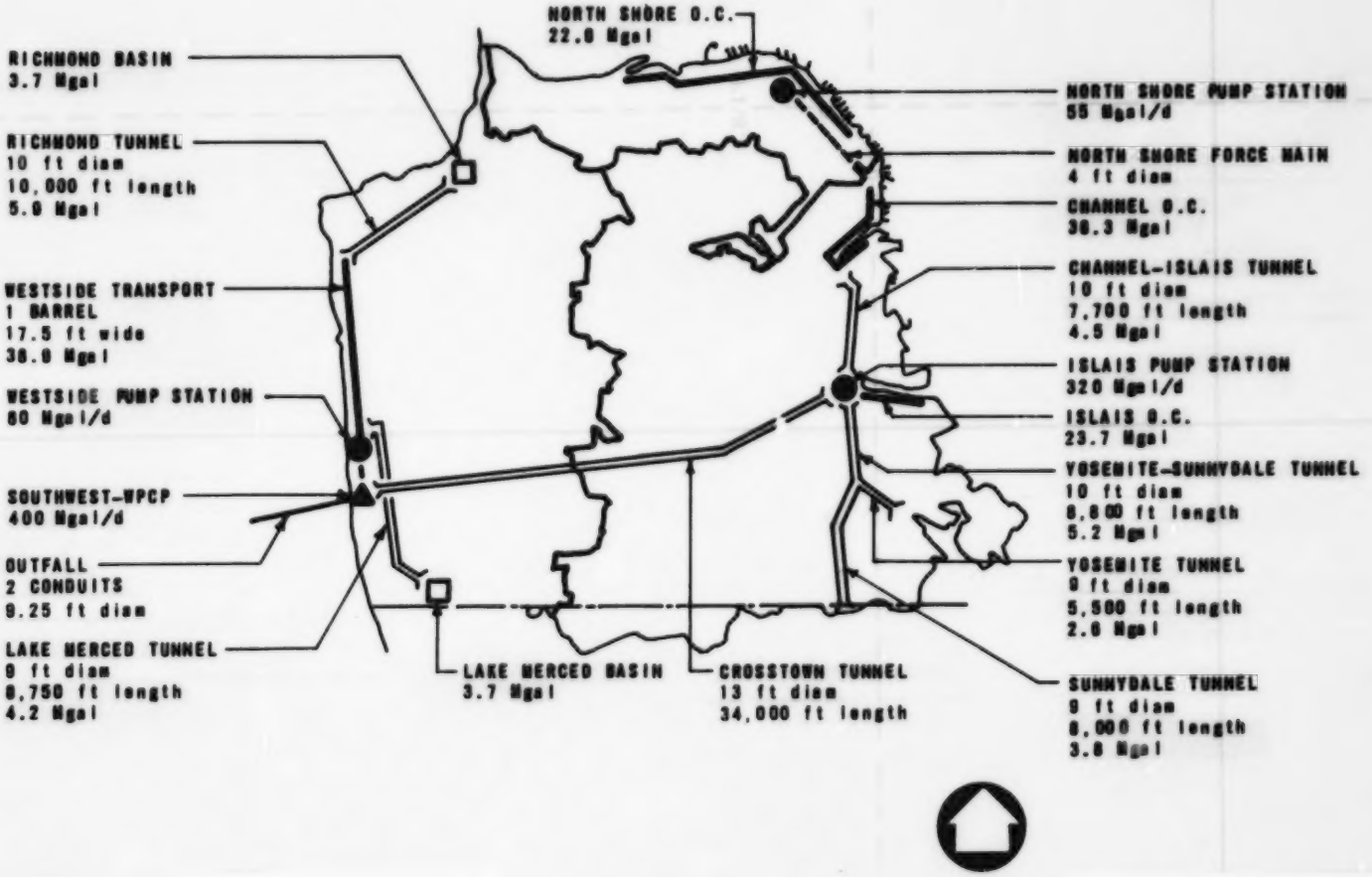


Figure 16. Schematic of apparent best alternative wet-weather system.

of the Southwest WPCP would have a peak capacity of 2.2 m^3/s (50 Mgal/d) and would treat all Westside dry-weather flows that would be conveyed to the plant by the same transport and pump facilties as Westside wet-weather flows.

North Shore and Southeast dry-weather flows would be treated at the expanded Southeast WPCP. Effluent from the Southeast WPCP would be pumped by the dry-weather pumps at Islais Creek pump station through a separate conduit in the Crosstown Tunnel. This effluent would be combined with dry-weather Southwest WPCP effluent prior to discharge in the ocean.

Sludge generated by the wet- and dry-weather facilities at the Southwest WPCP would be pumped from this plant to the Southeast WPCP through three pipelines embedded in the Crosstown Tunnel. The expanded Southeast WPCP would have facilities to treat and dispose sludge generated by both Southwest WPCP and Southeast WPCP.

LEVEL OF TREATMENT

Under provisions of Section 301(h) of the Clean Water Act of 1977 and under prior studies, the city has compiled extensive oceanographic and marine biological data in the vicinity of the Southwest Ocean Outfall site. These data support less than secondary treatment for west side dry-weather flows when discharged in a blend with bayside secondary effluent and question the necessity for higher than primary treatment for excess wet-weather flows. As a result, the city has filed with USEPA for a waiver of secondary treatment for westside dry-weather flows and has successfully petitioned the State Water Resources Control Board for a partial exemption from the Ocean Plan to allow primary treatment for excess wet-weather flows.

Based on these findings, the city is proceeding with the design of an integrated wet-weather and dry-weather primary plant at Southwest with an average dry-weather capacity of 1 m^3/s (22 Mgal/d) and a peak (citywide) wet-weather capacity of 20 m^3/s (450 Mgal/d). Initially sized for a peak wet-weather overflow rate of 73 $m^3/m^2 \cdot d$ (1,800 $gal/ft^2 \cdot d$), the sedimentation tanks will handle hydraulic loadings up to 110 $m^3/m^2 \cdot d$ (2,700 $gal/ft^2 \cdot d$) in the event the higher rate is justified by full scale performance. Designed for staged construction, the first stage Southwest plant (capable of handling all Westside flows) will have eight parallel, identical sedimentation basins, totally enclosed for odor control, mechanically equipped (conventional chain and flight collectors) sludge removal, and will be buried to facilitate zoo expansion and co-use of the site. Pretreatment will consist of mechanically cleaned screens (3/4 in. clear openings), velocity controlled grit chambers, and provisions for prechlorination for odor control. The pretreatment units and sedimentation basins are designed for modular, as needed operations under supervisory remote control from an onsite control center. Typically, these sedimentation tanks will handle all dry-weather needs and additional wet-weather tanks will be activated based on signaled stage readings from storage basins and remote rain gage recordings.

Adoption of primary treatment over biological secondary for dry-weather flows and chemically assisted primary for wet-weather flows is estimated to have reduced first costs by approximately $120 million (ENR 4000) and annual operation and maintenance costs by $3.5 million.

PERFORMANCE

The expected wet- and dry-weather effluent quality characteristics are shown in Table 18. The dry-weather effluent characteristics meet current NPDES requirements for ocean discharge. The wet-weather effluent characteristics, although known to vary due to the erratic nature of storms, are expected to meet ocean discharge requirements (with design minimum initial dilution of 27 to 1) with the exception of TSS. Neither the primary sedimentation nor the chemically assisted primary process meet the TSS removal requirement (75% removal under California Ocean Plan). Average dilutions are expected to range from 40 to 60 to 1. As examined and documented in the Ocean Waiver application, this TSS noncompliance should not adversely affect the ocean waters, marine organisms, or the indigenous fish population in the discharge zone.

Table 18. EXPECTED EFFLUENT QUALITY FROM SOUTHWEST WPCP

Parameter	Without waiver		With waiver	
	Dry weather[a]	Wet weather[b]	Dry weather[c]	Wet weather[d]
Grease and oil, mg/L	10	<25	13.8	24-41
Suspended solids, % removal	85	50-80	84.9	20-50
Settleable solids, mL/L·h	<1	<1	0.05	0.1-0.6
Turbidity, Jtu	<25	<25	19	46-60
pH, units	7.0 ± 0.5	7.0 ± 0.5	7.0	6.1-7.6
Toxicity, tu	1.25	<0.4	0.9	<0.6-1.5
Arsenic, mg/L	<0.0004	0.003	0.013	0.004
Cadmium, mg/L	<0.01	0.003	0.001	0.003
Total chromium, mg/L	<0.04	0.045	0.166	0.055
Copper, mg/L	0.04	0.103	0.030	0.125
Lead, mg/L	0.1	0.132	1.13	0.161
Mercury, mg/L	<0.0005	0.001	0.002	0.002
Nickel, mg/L	0.07	0.035	0.036	0.043
Silver, mg/L	0.03	0.014	0.005	0.016
Zinc, mg/L	0.03	0.637	0.168	0.779
Cyanide, mg/L	--	0.004	0.011	0.005
Phenolic compounds, mg/L	--	0.138	0.018	0.168
Total chlorine residual, mg/L	0.0	0.0	0.0	0.0
Ammonia nitrogen, mg/L as N	26	15.8	16.4	15.8
Toxicity, tu	1.25	<0.6	0.9	<0.6
TCP + PCBs, mg/L	--	--[e]	--[e]	--[e]

a. Westside flows alone treated to biological secondary.

b. Chemically assisted primary.

c. Westside primary blended with bayside secondary.

d. Primary treatment at 1,800 gal/ft^2·d.

e. Not detectable.

gal/ft^2·d x 0.0407 = m^3/m^2·d

The system effectiveness of overflow control of the selected master plan is compared to the existing conditions in Table 19. The selected master plan is expected to reduce untreated overflows and pollutant loads 80 to 90% below the existing conditions.

Table 19. SYSTEM EFFECTIVENESS[a] COMPARISON OF OVERFLOW REDUCTIONS

Item	Apparent best alternative	Existing conditions	Reduction, %
Overflow frequency[b,c]			
Westside	8	71[d]	89
North Shore	4	18[d]	78
Southeast	8	74	89
Hours of overflow			
Westside	42	300[d]	86
North Shore	13	136[d]	90
Southeast	30	234	87
Volume of overflow, Mgal			
Westside	473	2,068[d]	77
North Shore	58	472[d]	88
Southeast	690	3,621	81
BOD overflowed, 1,000 lb			
Westside	177	1,040[d]	83
North Shore	22	248[d]	91
Southeast	276	2,177	87
TSS overflowed, 1,000 lb			
Westside	552	2,763[d]	80
North Shore	66	592[d]	89
Southeast	816	5,002	84
Violation days[e]			
Westside	64	188[d]	66
North Shore	24	128[d]	81
Southeast	129	230	44
Percent of total wastewater treated (dry- and wet-weather combined)			
Systemwide	97.3	86.6	--

a. From 69-year SFMAC computer runs.

b. All values represent average annual over the test period.

c. Overflows based on tentative RWQCB definition: "An overflow event is any discharge from a group of interconnected diversion structures after maximum pumping or withdrawal rates are utilized consistent with downstream transport or treatment capabilities." Discharges separated by 12 or more hours constitute a separate overflow. Subsequently the SWRCB adopted a final separation interval of "6 or more hours."

d. Low existing condition numbers for North Shore and to a lesser extent Southeast are a resutl of Wastewater Program projects already committed.

e. Violation days are based on the most stringent coliform body contact standards (30 day, 20 percentile 1,000 MPN/100 mL) for Westside and North Shore and on the corresponding most stringent shellfish standards (30 day, 10 percentile >230 MPN/100 mL) for Southeast. Recent RWQCB tentative discharge permits for the North Shore and Westside sewage zones use a criterion of days greater than 1,000 MPN/100 mL in place of having averages that significantly reduce the number of technical violation days.

Mgal x 0.0438 = m^3
lb x 0.4536 = kg

This reduction in the number of combined sewer overflows is the most significant local water quality impact. The expected monthly distributions of average and maximum overflow events are listed in Table 20. Overflow events will occur only during large seasonal storms when storage and treatment plant capacities are exceeded. These overflows will be of an improved quality over the current discharges due to interception of the heavily polluted first portion of the runoff and baffles ahead of each overflow structure to retain floatable solids.

Table 20. MONTHLY DISTRIBUTION OF AVERAGE/EXPECTED MAXIMUM OVERFLOW OCCURRENCES UNDER THE APPARENT BEST ALTERNATIVE[a]

Location	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Westside	0/0	0/0	0/1	0/3	1/4	2/4	2/6	1/5	1/5	0/2	0/2	0/1
North Shore	0/0	0/0	0/1	0/2	1/4	1/4	1/5	1/3	0/2	0/2	0/1	0/0
Southeast	0/0	0/0	0/1	0/3	1/5	2/6	2/6	1/6	1/4	0/3	0/3	0/1

a. From 69-year SFMAC computer runs.

The selected master plan also would reduce the annual number of violation days by 40 to 80%, depending upon the shoreline location and violation day standard. The expected monthly distribution of average violation days is shown in Table 21. Both overflow and violation day analyses assume eight overflows/year for the Westside watershed; four overflows/year for North Shore, and eight overflows/year for the Southeast watershed. The latter is nominally equivalent to the wet-weather NPDES permit of 10 overflows/year for Central Basin and Islais Creek and 1 overflow/year for discharge south of Islais Creek.

Table 21. MONTHLY DISTRIBUTION OF VIOLATION DAYS UNDER APPARENT BEST ALTERNATIVE

Location	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Westside	0	0	0	1	5	11	15	15	10	6	1	0
North Shore	0	0	0	1	2	5	6	6	2	2	1	0
Southeast	0	0	1	6	13	19	24	23	21	16	5	3

a. Violation days are based on the most stringent coliform body contact standards (30-day, 20 percentile >1,000 MPN/100 mL) for Westside and North Shore and on the corresponding most stringent shellfish standards (30-day, 10 percentile >230 MPN/100 mL) for Southeast. Recent RWQCB tentative discharge permits for the North Shore and Westside sewerage zones use a criterion of days greater than 1,000 MPN/100 mL in place of having averages that significantly reduce the number of technical violation days.

b. From 69-year SFMAC computer runs.

OPERATION AND MAINTENANCE

To maintain flows at or below optimal treatment design rates, pump stations would regulate wastewater flows to the proposed Southwest WPCP. Together with the large storage volumes within the transport systems upstream of these pump stations, the selected master plan would have the flexibility and flow equalization capacity to optimize system performance in response to varying storm patterns.

Control signals initiated or monitored at Southwest WPCP could be used to activate or override local pump station controls for pump cycling:

- To prevent treatment plant overloads
- To shift treatment capacity to areas of greatest need
- To control storage pumpdown after storms.

By monitoring pump station operations at Southwest WPCP, the plant operator will know how many modular process units to bring online during a storm event.

Based on SFMAC simulations, wet-weather Southwest WPCP operation is shown in Table 22. Average annual and monthly, as well as the worst monthly, operation is presented in the table. During an average year, the wet-weather facilities are expected to be operated 633 hours and be started up for 69 storm events, primarily from November to April. During 39% of the operation, the wet-weather facilities will run at the peak capacity of 1,514 m^3/d (400 Mgal/d). Flows to these facilities will average less than one-half of this peak capacity 50% of the operation time.

Additional operating time will be required for post-storm cleanup, typically 24 to 72 hours per storm, and for routine maintenance and testing of the wet-weather equipment. Full-time operation and maintenance crews will be necessary during the rainy season. A dry-season maintenace crew may be required as well.

The dry-weather facilities at Southwest WPCP will be staffed and operated 24 hours a day, 7 days a week. During off-season storms, the staff may be able to use storage equalization and hydraulic overloading of the dry-weather facilities to minimize the off-season startups of the wet-weather facilities. If a storm occurs requiring wet-weather facilities activation, the off-season wet-weather maintenance crew, assisted by personnel from the dry-weather facilities, could activate and operate the wet-weather facilities.

Table 22. SELECTED COMPUTED INFLUENT LOADINGS TO SOUTHWEST WPCP WET-WEATHER PLANT[a]

Item	January 1958 (typical January)	January 1916 (maximum month on record)	Average annual (69 years)
No. of plant starts			
Minimum of 1-hour shutdown between starts	8	26	69
Minimum of 6-hour shutdown between starts	6	15	--
Minimum of 12-hour shutdown between starts	6	8	38
Hours of operation			
Total (excluding cleanup)	122	368	633
Percent of time at 400 Mgal/d	55	46	39
Percent of time >320 Mgal/d	55	48	41
Percent of time >240 Mgal/d	58	52	45
Percent of time >160 Mgal/d	61	59	51
Percent of time >80 Mgal/d	70	73	65
Percent of time >0 Mgal/d	100	100	100
Longest continuous run, h	34	49	--
BOD_5 loading, lb/h			
Maximum hour	19,943	20,832	23,749
Average hourly	7,340	6,164	6,239
TSS loading, lb/h			
Maximum hour	37,609	37,781	38,849
Average hourly	15,988	13,283	12,990

a. From SFMAC simulation of apparent best alternative.

Mgal x 0.0438 = m^3
lb x 0.4536 = kg

COSTS

Capital and operation and maintenance costs at ENR 4000 of the selected master plan are presented in Table 23 and the general cost relationships are illustrated in Figure 17. The capital cost is $1,350 million if secondary treatment for dry-weather flows and chemically assisted primary for wet-weather flows are waived. Total waiver system operation and maintenance is $17 million. These capital costs include approximately $450 million for wastewater management facilities already completed or under construction.

It should be noted that wet-weather elements make up nearly 70% of the total capital cost but only 10% of the annual operation and maintenance costs. Based on the total service area, the wet-weather capital costs average $81,510/ha ($33,000/acre) (ENR 4000) which is typical of earlier findings [6, 7] for comprehensive combined sewer overflow solutions for fully developed urban areas.

Table 23. SYSTEMWIDE COSTS OF THE SELECTED MASTER PLAN
Millions of Dollars, ENR 4000

	Capital[a]	Annual operation and maintenance
Wet weather		
Storage/transport	416.2	0.21
Pumping and conveyance	227.9	0.59
Treatment (including sludge processing)	175.2	0.81
Effluent disposal	123.0	0.15
Subtotal	942.3	1.76
Dry weather		
Storage/transport	--	3.76
Pumping and conveyance	33.8	1.66
Treatment (including sludge processing)	272.8	9.22
Effluent disposal	108.1	0.76
Subtotal	414.7	15.40
Total	1,357.0	17.16

a. Costs include an allowance, nominally 25%, for administration, engineering, and construction contingencies.

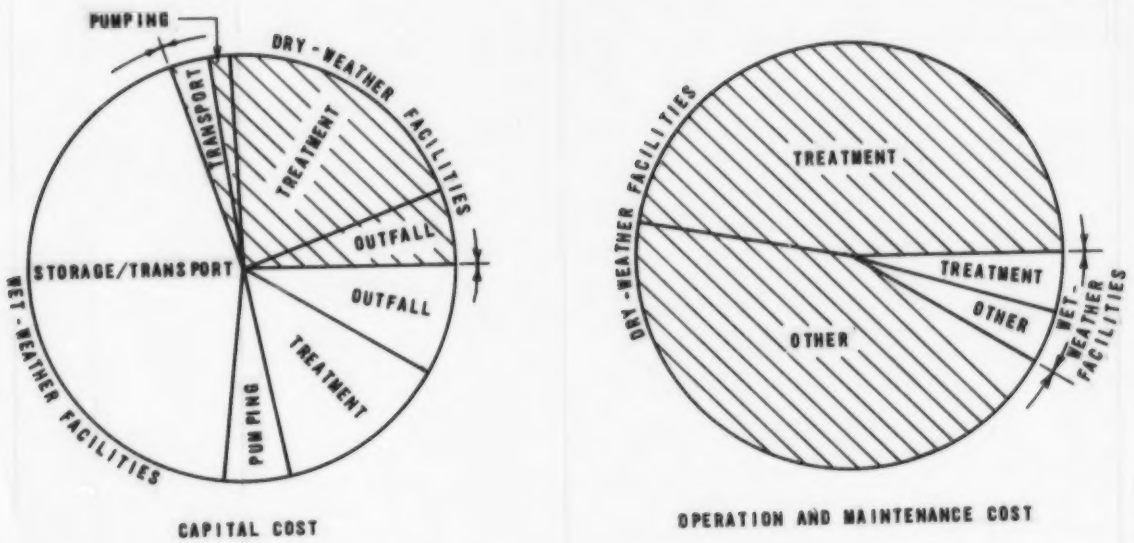


Figure 17. Generalized cost allocations.

ENVIRONMENTAL/SOCIOECONOMIC BENEFITS

There are two main environmental impacts of the selected master plan, each dependent on the other:

- Conformance with water quality objectives
- Improvement of receiving water quality

The proposed system will conform with the Basin Plan, NPDES discharge permits, and the Ocean Plan. The number of active overflow structures will be reduced and the only treatment plant bypass, at Richmond-Sunset WPCP, will be eliminated. Water quality will improve through the elimination of dry-weather effluent discharges to the bay and the large reduction of combined sewage overflows to both the bay and ocean during wet-weather.

Under this master plan approximately 136,000 kg (300,000 lb) BOD and 408,000 kg (900,000 lb) TSS will be discharged annually into the bay, reduced from 5,000,000 lb kg (11,000,000 lb) BOD and 6,400,000 kg (14,000,000 lb) TSS in the existing condition. These discharges will only occur during large storms when storage and treatment capacities are exceeded.

Socioeconomic impacts are products of the environmental impacts. Commercial and recreational fishing could increase by improving bay and ocean water quality. This improvement could also contribute to the revitalization of the bay's once prominent shellfish industry. Waterfront recreation, in the forms of swimming, diving, sailing, boating, beachcombing, and surfing, could also be enhanced. Shoreline aesthetics can improve with the reduction of overflows and associated floatables.

The proposed Southwest WPCP is to be located south of the zoo and west of Lake Merced along the recreational ocean shoreline. By constructing major components of the plant underground and properly landscaping it, the site will be compatible with the proposed zoo expansion. Mitigation measures, such as odor control and noise abatement, will be incorporated to minimize impacts to the surrounding environment.

SECTION 6

CONTINUING ANALYSIS

As illustrated earlier in the chronology of plan development, there is a continuing interplay between public concerns over environmental quality, regulatory direction, technical achievements, and financial capabilities and responsibilities. Like the TARP project in Chicago [6], the San Francisco Clean Water Project is so massive, dwarfing all previous city public works projects in scope and cost, it is sensitive and susceptable to decisions locally, regionally, and nationally. The foremost concerns are funding and inflation.

In 1978, 11% of the National Clean Water Grant funds went to California and of these almost 40% went to San Francisco. In 1979, the figures dropped to approximately 7% and 13%, respectively, as major project elements were deferred pending reviews, clearances, and determinations of continued grant funding constraints. In the present (January 1981) inflationary environment, the prevailing 12% compounded rate represents an element cost doubling every 6 years. In response to these concerns, the city has adopted a staged construction program, as shown in Figure 18, aimed at extending the life and expanding the role of its existing and committed facilities, while at the same time authorizing only those future projects that will be operable and useful within the limits of its assured funding commitments.

Construction priorities presently are:

1. To complete a "core" system on the bayside for wet-weather treatment to augment the committed dry-weather system and to fully utilize committed storage/transport projects. This will involve continued wet-weather service from the existing North Point plant plus testing of "split" flow treatment at the expanded Southeast plant. The split flow concept envisions running the primary and secondary unit processes in parallel during storm conditions to double the potential throughput.

2. To construct a similar core system on the west side consisting of a storage/transport element, a primary treatment facility for both dry- and wet-weather flows, and a deep ocean outfall.

3. To construct a crosstown conveyance bringing dry-weather secondary effluent west for deep ocean blended discharge with west side primary flows (thus meeting waiver conditions) and west side sludge east to the Southeast plant for processing.

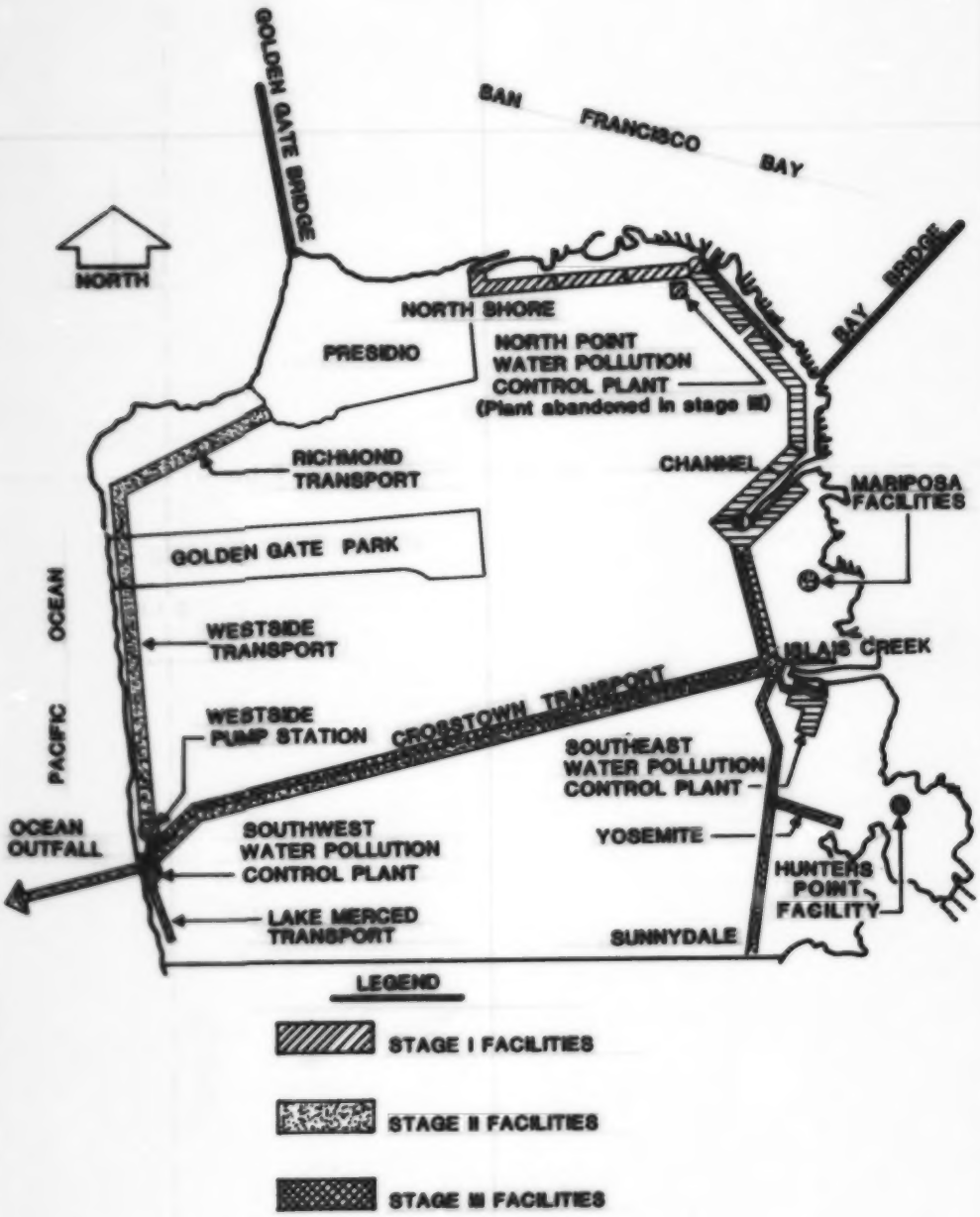


Figure 18. Program for Staged Construction [8].

4. To construct additional storage/transport facilities to bring the level of control up to the master plan criteria.

The estimated fully inflated cost to this Stage II goal (Stage I is defined as projects committed as of June 1980), is $1.6 billion and it is estimated that the facilities could be complete and online by 1986-1990. Stage III, the balance of the program (essentially the conveyance of bayside wet-weather flows to Southwest for treatment and ocean disposal) would be implemented as funds become available and as the need was demonstrated.

In addition to the above, the city is continuing to test higher loading rates on the wet-weather primary treatment facilities which, if successful, will reduce wet-weather treatment first costs by as much as 30%. Also, in keeping with the staged program objectives, a single barrel outfall option has been selected with the combined discharge approximately 6 km (4 miles) offshore. Advantages include higher initial dilution for wet-weather flow (minimum initial dilution of approximately 45:1 versus 27:1), reduced biofouling of discharge ports, and lower Stage II costs. Under Stage III, for short periods (peak wet-weather flows coincident with high tides), effluent pumping will be required.

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